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MINUTEMAN WING I ENVIRONMENTAL CONTROL SYSTEM RELIABILITY ANALYSIS REPORT

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ABSTRACT

This report is an evaluation of environmental control system reliability data supplied by an Associate Contractor and subcontractors for Air Force Minuteman Wing I. The data submitted by American Air Filter Co. are found to be a fair estimate of Mean Time Between Failures (MTBF), although modifying factors were not always applied. The data supplied by Holladay and Westcott were found to be unrealistic, mainly because not all sources of data were considered.

Recommendations for system upgrading are made by STL for future Wings of the Minuteman Program. These recommendations include such things as overdesign allowances, redundancy, use of best equipment, complete failure reporting, and use of modifying factors for correct determination of MTBF.

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ILLUSTRATIONS

I. PURPOSE

This report presents an STL reliability evaluation of the American Air Filter (AAF) report, "Reliability Report, Environmental Control Systems WS 133A Technical Facilities AF 04(647)-689," dated 1 November 1961, and a similar AAF report dated 20 April 1962. The evaluation also covers the Holladay and Westcott "WS 133A Technical Facilities Environmental Control System Study Final Report," dated 21 May 1962. Analyses submitted under the AAF report dated November 1961, hereinafter referred to as Reference 1, are based upon design parameters and reliability data established on or before 19 September 1961. The April report is based upon systems data updated to 6 April 1962. No evaluation of Engineering Change Proposal (ECP) or other change action put into effect subsequent to that date is attempted. The Holladay and Westcott report, hereinafter referred to as Reference 2, is an evaluation of Reference 1.

A secondary purpose of this report is to present the position of the STL Reliability Staff. This position is based on evaluation of the major systems, subsystems, and components of the environmental control system of Minuteman Wing I.

II. INTRODUCTION

Air Force Minuteman Wing I operation requires that each of the three major types of ground support installation control functions be equipped with environmental control. Thus, the primary function of the AAF-supplied environmental control system equipment is to maintain and control the environment of the Launch Control Facility (LCF) Launch Control Center (LCC), the LCF Strategic Remote Control Center (SRCC), and the Launch Facility (LF). This function includes temperature and air-conditioning control for both electronic systems equipment and personnel. Air purification is a requirement for both normal and emergency operation. Emergency operation of the systems is accomplished by automatic switching from the normal mode under conditions of power failure or other emergency conditions. Diesel generators or batteries provide a power source under these conditions through automatic switching devices. The Wing I complex includes 150 installations of the Launch Facility type, 13 of the Launch Control Center type, and 2 of the Strategic Remote Control Center type.

Figure 1 is a cutaway view of a typical Launch Facility. The environmental control equipment serving the Launch Facility provides conditioned air at closely controlled humidity and temperature levels to the installed electronic equipment packages. Cooling air is also provided to the general equipment area, and supplementary heated and controlled air is ducted into the launch tube. Extremely complex control equipment is not required to enable the air-conditioning system to provide close temperature and humidity control in the launcher. This is because the launcher is totally enclosed and has no attending personnel. The control system for the launch tube heater is relatively simple, since the launch tube has a nearly constant heating load.

Figure 1a illustrates the environmental control system arrangement within the Launcher and the Launch Support Building.

Figure 2 is a cutaway view of a typical Launch Control Center. The location of the environmental control system equipment is shown in Figure 2a. The environmental control equipment utilized in this installation is required not only for closely controlling the temperature and the humidity of the air supplied to the electronic equipment in the LCC, but also to

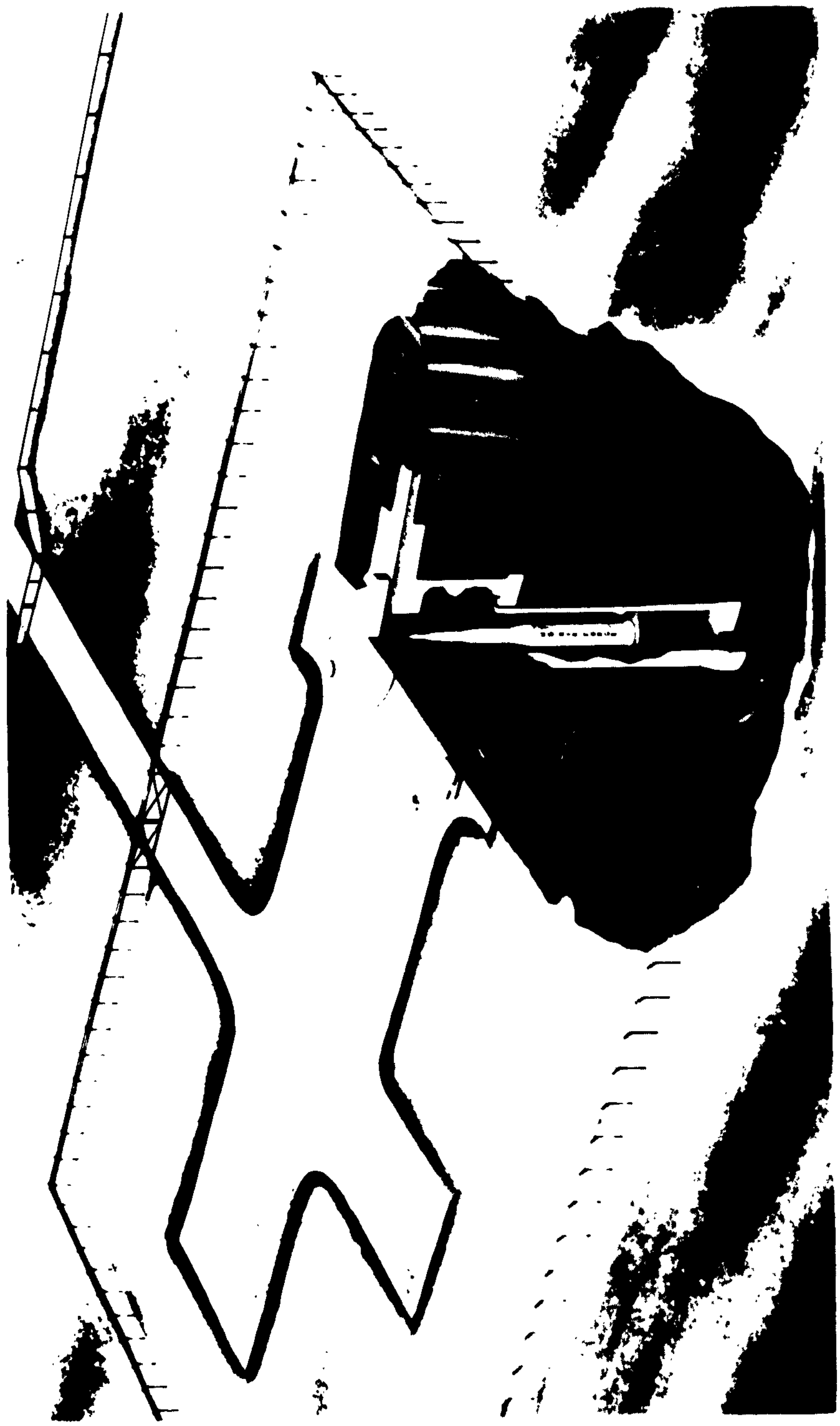
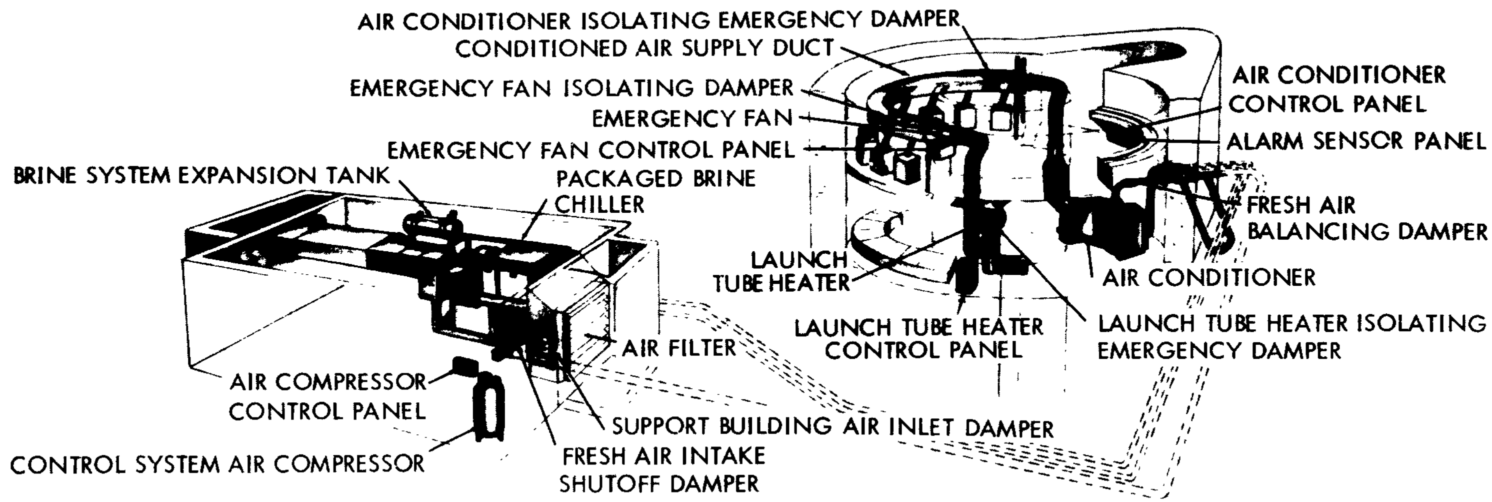


Figure 1. Typical Minuteman Launcher



EQUIPMENT PLACEMENT, SUPPORT BUILDING

EQUIPMENT PLACEMENT, LAUNCHER

Figure la. Launch Facility Environmental Control System

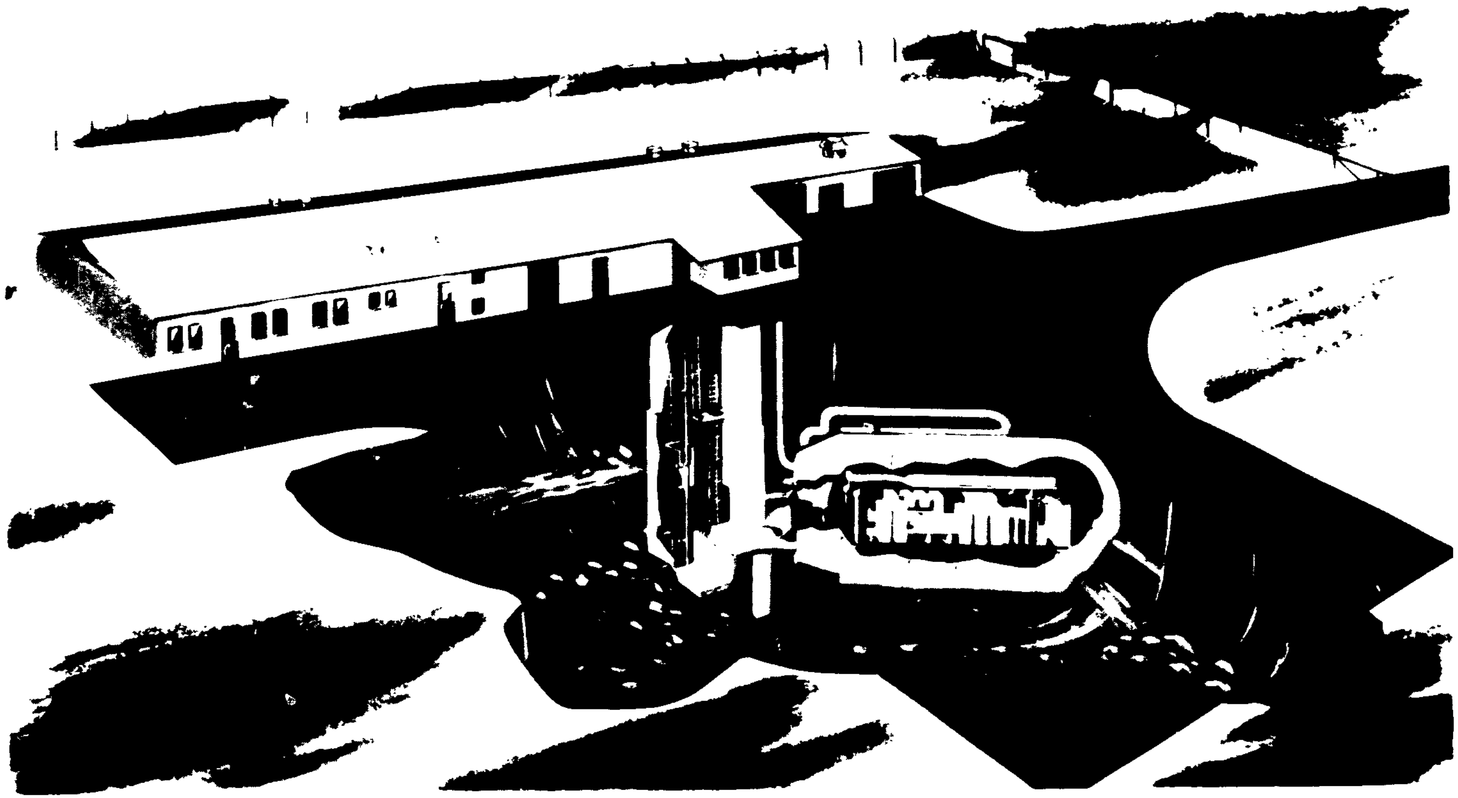


Figure 2. Typical Launch Control Center

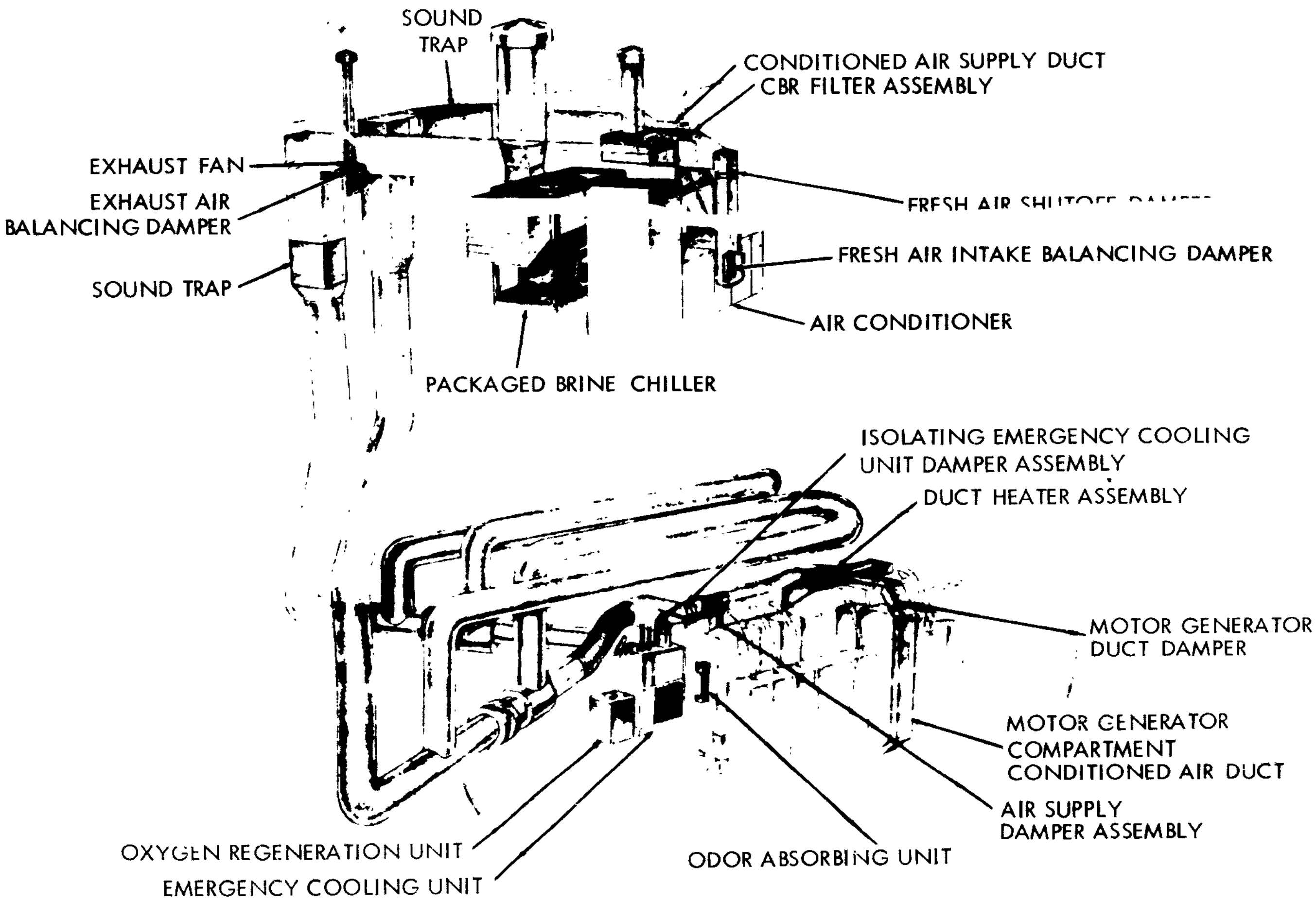


Figure 2a. Launch Control Center Environmental Control System

provide suitable environment for the occupants. A battery compartment is also ventilated. The main components of this system, the packaged brine chiller and the air-conditioner package, are located above ground in the support building, and conditioned air is ducted down into the control center as schematically indicated in Figure 2b.

The SRCC type of LCF serves the same purpose remotely, as the LCC mentioned above. The equipment is also very similar, with the exception of the requirement for two air conditioners and two brine chillers, which provide additional conditioned air capability. The double air-conditioner, brine chiller arrangement requires an additional sequence-starting auxiliary panel in the support building to provide sequence starting of the second units and to provide instrument air pressure to the control center from whichever air-conditioner unit is operating. A cumulator system is added to provide a delay between the starting of the two brine chillers. Equipment locations are illustrated in Figure 3.

Much of the equipment used is identical for all three types of facility. Packaged brine chillers in the LF and LCF are identical; packaged air-conditioners are identical. Alarm systems and use of filters are very similar. Most of the smaller components are identical. And, as noted above, the two types of LCF utilize identical components, with the exception of the sequencing arrangement. From the reliability standpoint, use of identical components is good not only because of inherent simplification, but because failures in one area may well be applicable by cause or remedy to another area. It is also very desirable from a logistics viewpoint. Table 1 is a subsystem breakdown of the systems involved in the Minuteman environmental control system installations.

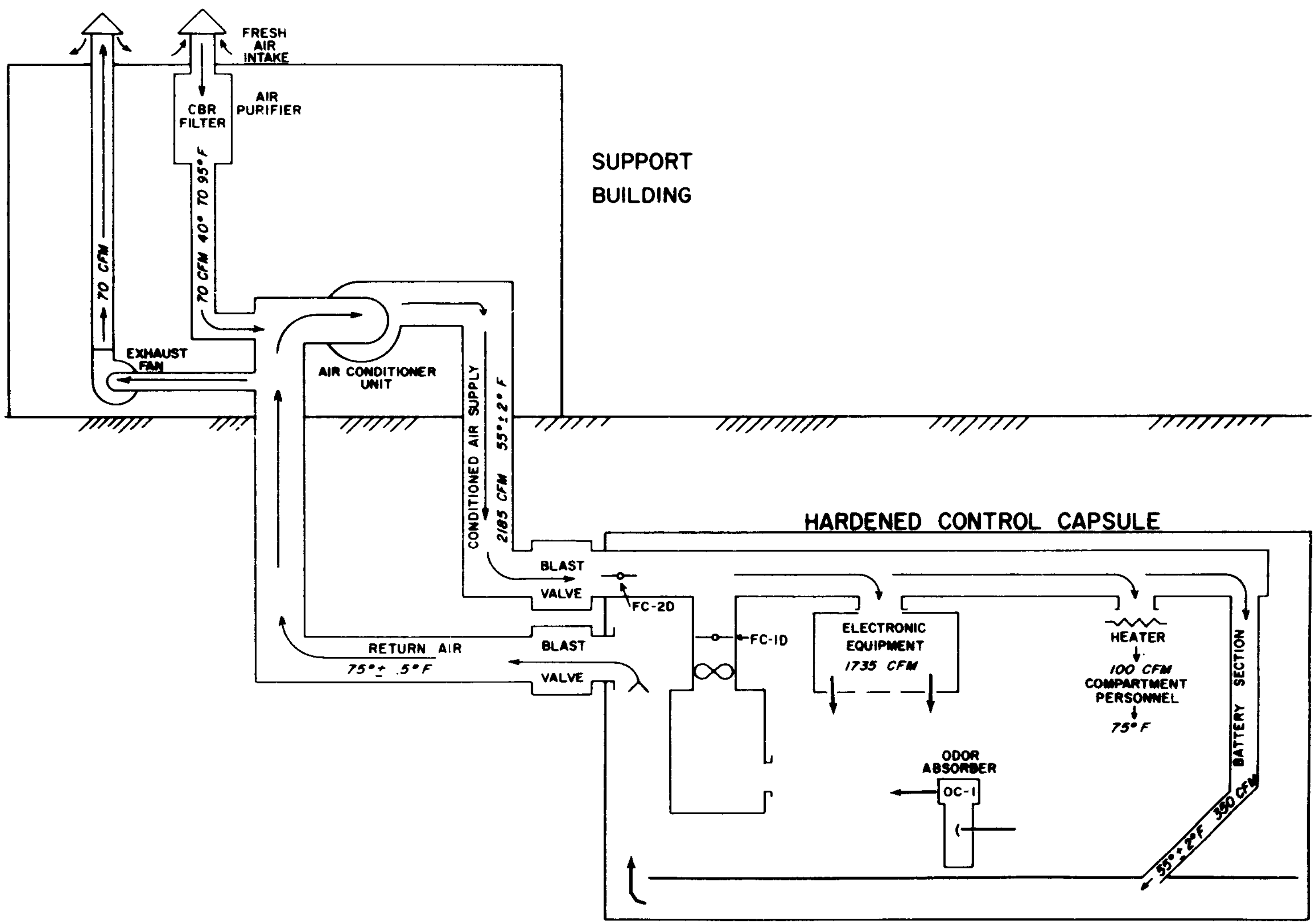


Figure 2b. Conditioned Air Flow in Launch Control Center

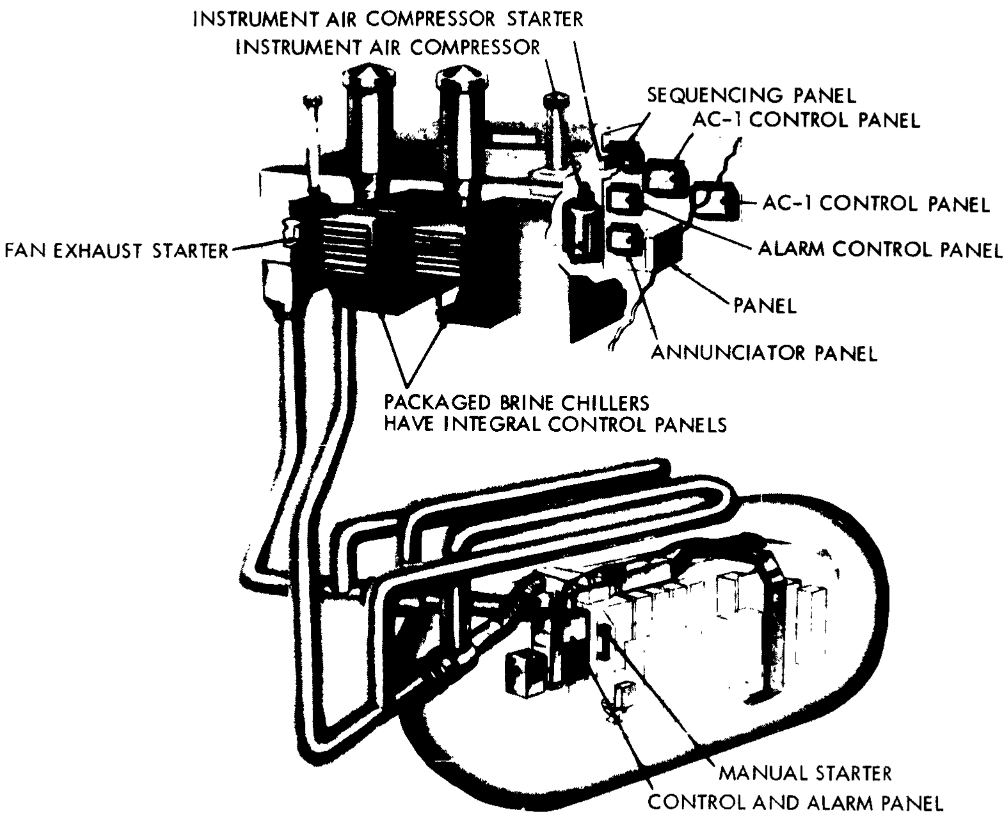


Figure 3. Launch Control Facility (SRCC)
Environmental Control System

Table 1. Environmental Control System Facilities and Subsystems

Facility and Subsystem	Quantity
LCF(SRCC) Normal	2
A. Air Handling - Support Building	2
B. Packaged Brine Chiller	1
C. Air Handling (LCF-SRCC) (LCF-LCC)	1
D. Normal Operating Emergency Water Storage	1
E. Exhaust Air System	1
F. Control Air Supply	1
LCF(LCC) Normal	
A. Air Handling - Support Building	1
B. Packaged Brine Chiller	1
C. Air Handling (LCF-SRCC) (LCF-LCC)	1
D. Normal Operating Emergency Water Storage	1
E. Exhaust Air System	1
F. Control Air Supply	1
LF Normal	
B. Packaged Brine Chiller	1
F. Control Air Supply	1
K. Air Handling - Launcher	1
L. Launch Tube Heater System	1
LCF(SRCC) Emergency	
G. Emergency Air Handling	1
H. Emergency Chilled Water	1
J. Emergency Air Purification	1
LCF(LCC) Emergency	
G. Emergency Air Handling	1
H. Emergency Chilled Water	1
J. Emergency Air Purification	1
LF Emergency	
M. Emergency Air - Launcher	1

III. DISCUSSION

In the two previous studies of component failure rate data and their system summations which have been performed, the differences indicated in MTBF for the environmental control systems were highly significant, and consequently an independent evaluation was considered mandatory.

This section of the report, then, will cover STL evaluation of failure data and its use of References 1 and 2. The final part of the discussion will present the STL evaluation position on the environmental control systems and the basis for independent prediction of MTBF of major subsystems.

Members of the STL Mechanics Division Reliability Staff, who are supporting the Minuteman Environmental Controls Project Office, reviewed Reference 1 and the pertinent backup data utilized by AAF, at St. Louis, Missouri. The objectives of this evaluation were threefold:

a) To ascertain if AAF backup data were valid and collected objectively from the respective system component industry.

b) To determine if derating and application factors used by AAF were valid and applied realistically.

c) To impartially evaluate the reliability failure rate data section of Reference 2, which in turn is a review of Reference 1.

EVALUATION OF REPORTS

Evaluation of Reports by AAF

Failure Data. With respect to failure data, it was established that if the component failure rate backup data gathered by AAF from throughout the industry upon examination were found to be valid, then these failure rates would be acceptable to STL and used in this report. STL consideres that for the most part the failure rate backup data which were reviewed were gathered and analyzed objectively by AAF. Inasmuch as approximately 80 percent of the component failure rates significantly affect the final MTBF's, all of these failure rates were checked and the remaining items were spot-checked for validity.

There are several instances where AAF for various reasons does not have backup data for the published failure rates. These failure rates are identified as "AAF estimates" and include such parts as electrical connectors, cablings, ducts, and shock attenuators. Since no background is given for the estimates in these cases, evaluation of the data is necessary on the basis of other sources available to STL. Some of these part estimates made by AAF appear quite optimistic.

Another criticism of the AAF data concerns the failure rate estimates for miscellaneous equipment. Failure data were often obtained for unspecified numbers, sizes, or lengths of ducts, piping connections, etc. Unless failure rate is specified as per "unit" and the number of units given, the resultant estimate is quite variable and can lead to large variations in failure rate estimations.

An overall comparison of "static" and "dynamic" component failure rates in the AAF report at first glance indicates some apparent inconsistencies. For example, a component that is stationary or nonoperating would generally be expected to have a lower failure rate than an operating or moving component. It may even be expected that if all components were listed in order of increasing failure rates, all static components would be at the beginning of the list. However, this is not the case. Use requirements do not allow an absolute list. For example, the number of operating cycles is an important factor. A complex solenoid valve which may operate once at system start would have a lower failure rate than a solenoid valve which may be constantly cycling, or difference in failure rates may be due to variation in physical location of comparable components. Failure rates of many operating components are very low. The few cases in the AAF report which appear inconsistent do not constitute significant error.

It may be noted that AAF has, in St. Louis, separate files for correspondence collected during the past year and a half from the many manufacturers of components which are utilized in the control systems. From

this compilation they have extracted the major portion of their published failure rates. In short, a considerable effort has been made, and it is considered that generally the basic failure rate backup data collected by AAF are as good as was possible to obtain under existing industrial conditions. Consequently, the majority of the failure rates published in Reference 1 have been at least basically utilized in the STL report without major modification, except where notations indicate otherwise.

Modifying Factors. The component derating or application factors utilized by AAF fall into the general categories of operational probability use, system use or location, and design load derating. Most of the data supplied by various manufacturers to AAF were submitted as basic data; i.e., a report of hours of use and number of failures. In general, no "use" or other multiplying or derating factors were supplied, so that in estimating failure rates for the Wing I system, AAF used those factors they considered applicable to the basic submitted data. The factor most often applied by AAF is an "operational use" factor to account for anticipated less-frequent operation of the equipment for the particular Minuteman environmental system. In most instances, this is a direct ratio of operational times. For the most part, these factors applied by AAF are realistic and approximate STL system use predictions. In a few instances, however, a derating or application factor estimated by AAF appeared unrealistic and was changed in the STL evaluation.

In some cases the manufacturer's failure rate data were submitted as an "observed operating time" or as "cycles," with no failures apparently having occurred. AAF applied a no-failure "equal probability" factor of 0.7 MTBF to the total accumulated time or number of cycles to obtain an estimate of the MTBF. This is considered to be a valid statistical factor.

Unfortunately, several drawbacks to complete evaluation of AAF use of derating factors are extant. For one thing, the environmental conditions for each piece of equipment must be known in order to properly evaluate application factors which should be applied in Reference 1. These conditions are not indicated in Reference 1, nor is there documentary evidence that AAF actually often took them into consideration. Where the AAF failure data are given simply as an "AAF estimate," no evaluation of the

background or application factor modifying influence can be made. In these cases informal discussion with AAF reliability personnel was the only basis for either agreeing or disagreeing with both the basic failure rate and any influencing application factors. In addition, very little load or stress or design margin information is evident. Where this information was given, an evaluation was made by STL, and in most cases the data were sound, but in general there seems to be little of this information.

One area completely ignored in Reference 1 is a factor which may be considered in the form of a multiplying factor greater than one, which is required to take into account nonreporting of failures in the basic data. This is of prime importance in the final determination of failure rates. A follow-on to this consideration is an evaluation of the breakdown of the reported failures into pertinent and nonpertinent failures. Both concepts are given additional consideration later in this report.

Overall, the multiplying or application factors utilized by AAF represent a fair use. However, some disagreements with the AAF factors exist, including, for example, the manual water valve (Subsystem B), where the STL modifying factor is 1.00, versus 0.50 in Reference 1; electric motors, manufactured by Reliance Electric Motor Company, had failure rates factored by 0.50 by STL, versus 1.00 by Reference 1; and centrifugal pumps with special seals (Subsystem B) were assigned an application factor by STL of 0.10 of the Reference 1 value. By and large, though, the AAF values seem representative of good engineering judgment toward adaptation of known component failure rates to particular system time use.

Evaluation of Report by Holladay and Westcott

There is a vast difference in the failure rates of identical components listed by Reference 1 and those of Reference 2. While there normally would be some disparities in failure definition, etc., many of the differences indicated here are extreme. This is so, even though the same analytical methods, failure rate backup data, and known component generic failure rate data were supposedly available to each. As the backup data and analytical methods employed by AAF, Reference 1, are reviewed and compared generally with those of Holladay and Westcott, Reference 2, several characteristics of both presentations become increasingly evident.

a) The tabulated AAF failure rates are frequently very low—much lower than those tabulated in the reliability section of the Holladay and Westcott report, in which the failure rates are based almost entirely upon published component generic failure rates.

b) The AAF failure numbers are based mainly upon apparently valid subcontractor or component manufacturer failure data. Where no manufacturer failure data exists, the AAF estimate is reasonable in most instances, very low in others.

c) Reasonable system application factors or derating techniques were employed extensively by AAF. This type of application or multiplying derating factor was not used in the reliability section calculations of the Holladay and Westcott report.

A close check of the failure rates used in Reference 2 reveals that the mean value given in a reliability analysis by AVCO Corporation, Reference 3, for generic failure rates was usually used. While the use of the generic type of number is acceptable for estimating or for preliminary reliability evaluation, it exhibits several important shortcomings:

a) No use is made of the failure data from the manufacturer or the specific component. Uniqueness is bypassed.

b) Consideration of application of a component in a particular system is excluded.

c) Consideration of failure rate modifiers for location in a system is excluded.

d) Consideration of changing or of different environment operating conditions is excluded.

e) Design or loading margins are not considered.

f) No allowance is made for changed values for components due to updating state-of-the-art designs.

The STL Reliability Staff regards the use of individual, demonstrated component failure rate data determined by the component manufacturer to be superior in accuracy to average or mean generic rates when applied to a detailed system operation. For example, power dampers, which are simply shaft-mounted flappers supported in a duct, are listed by the Holladay and Westcott report under "Structures" with a mean failure value of $1.00/10^6$ hours. The AAF value based upon field use of 485 units over

a 4-year period is $0.137/10^6$ hours, roughly a difference of one magnitude. The damper operator which is listed by Holladay and Westcott as an "electric motor" with mean failure rate of 0.300 is not an electric motor, but an air cylinder with a failure rate value determined by the manufacturer to be 0.00045. The Holladay and Westcott report lists the failure rates for all electric motors, regardless of size, rating, type, or use, as 0.30, whereas AAF uses several values, depending upon the type of motor, ranging up to 8.90. The flow controller listed by AAF with a failure rate of 0.00055 is listed by Holladay and Wescott under general flow and pressure regulators with a 2.140 mean failure rate. The foregoing figures do not include application or multiplying factors and are, therefore, comparable. These are only a few examples of the listed failure rate differences which account, in part, for ultimate MTBF estimate differences.

In addition to the limitations imposed by the use of generic failure rates as indicated above, other shortcomings with Reference 2 are evident. There is little indication that an attempt to check out or validate the AAF backup data was made. Component manufacturer's failure data were apparently considered inferior to generic failure data even where many hours of practical operation of a component or much test time was in evidence. A check made with the initiator of Reference 1 indicated that no contact was made with them to verify failure rates of equipments which they manufacture or for which they are responsible. In addition, the writers of Reference 2 are quite critical of methods and procedures utilized in Reference 1 without themselves using methods and data above question. In short, the evaluation made in Reference 2 severely criticizes the Reference 1 report without giving a detailed examination of the methods and data used in Reference 1.

On the other hand, it is recognized that use of component manufacturer's data alone and without regard for established generic failure rates may be undesirable. The position taken by the STL reviewers throughout the evaluation was to utilize the available component manufacturer's data that was considered well founded and documented and rely on generic or similar component general failure rates only when necessary. For these reasons, closer agreement will be noted with Reference 1 failure rate totals and MTBF's, than with those of Reference 2.

STL EVALUATION POSITION

After review of the failure data presented by AAF and evaluation of the report by Holladay and Westcott, modifying and application factors were applied to the basic failure information. It was concluded that while many of the criticisms made in Reference 2 were valid, the final failure data values were not as applicable to valid MTBF determinations as those given in Reference 1.

This part of the report presents the STL prediction of MTBF versus the required MTBF for the three main environmental subsystems: LCF(SRCC) Normal, LCF(LCC) Normal, and LF Normal.

The fundamental reliability structure of the systems as depicted in block diagrams of Reference 1 and found applicable to Reference 2 was closely scrutinized. The minor subsystems are composed in such a way that the reliability structure of each minor subsystem and of each major subsystem as a combination of these minor subsystems is series in nature. Failure of any component results in failure of a minor subsystem, and failure of any minor subsystem results in a major subsystem failure. The more common failure distribution functions are the exponential, binomial, normal, gamma, and Weibull. The exponential is a special case of the gamma and Weibull and has been shown to give a good reliability estimate of grouped electronics and electromechanical parts after burn-in period and before wearout. This is during the random failure period when the probability of failure is constant. Following the reasonable assumption that the reliability of these mechanical and electromechanical components follows the exponential law of reliability, $R = e^{-\lambda T}$, and that the reliability of the entire system or subsystem is the product of the reliabilities of its parts, then by the laws of exponents, the failure rate of the system is equal to the sum of failure rates of its total subsystems. This concept is represented by the following (where λ represents failure rate of minor subsystems):

$$\text{Reliability of system} = R_s = R_1 \times R_2 \times R_3 \cdots R_n$$

where

R_1 = reliability of subsystem 1,

R_2 = reliability of subsystem 2, etc.

and since,

$$R = e^{-\lambda T}$$

$$e^{-\lambda_s T} = e^{-\lambda_1 T} \times e^{-\lambda_2 T} \cdots e^{-\lambda_n T}$$

$$e^{-\lambda_s T} = e^{-(\Sigma\lambda_i)T}$$

then system failure rate

$$\lambda_{subsystem} = \Sigma\lambda_i$$

and also

$$\text{system MTBF} = \frac{1}{\lambda_{subsystem}}$$

However, a summary review of major and minor subsystem operation by STL to ascertain the validity of the series relationship concept resulted in the discovery of questionable areas involving the alarm systems and the emergency water storage subsystem of the LCF-type facility.

Certain subsystems are equipped with a group of components which will function to warn the Control Center of malfunctions within that system. Generally there is an allowable time in which the malfunction can be corrected while the system continues operating. The question as to the validity of including these alarm components in series with the system functioning components has been raised, since both References 1 and 2 have so included them. However, it must be pointed out that the alarm components do not themselves cause a system shutdown. Their importance, therefore, in regard to criticality of failure is much less than a failure of a series-involved functioning component. The problem then is how to include alarm system component failure in the reliability calculation of system MTBF. If, as in normal reliability methods practice, the alarm system is included as a parallel function to the subsystem it protects, then the only complete (critical) failure would be the simultaneous failure of both the alarm system and its protected subsystem. For example, subsystem L of the Launch Tube Heater System is protected by an alarm system which serves to notify the Control Center of an unacceptable temperature level possibly resulting in a major system and even a Weapon System operational failure. In the protected subsystem as illustrated below, we note very little system

reliability enhancement from the alarm system at low or initial system operating times. If we were to consider no system inspection or maintenance over a period of as long as 3 years, we could calculate a system reliability increase at the end of this period of nearly 13 percent over a functioning system without alarm protection. This increase, while important to system function, becomes much less significant from a realibility standpoint, however, when we consider the more probable informal maintenance-inspection functions within 90-day periods. As noted in the sample, a system reliability increase of approximately one percent may be expected in an alarm-protected system over a nonprotected system for a 3-month operation, provided the MTBF equivalents noted in Exhibit II, STL-April column, are used.

In summation, the following observations concerning alarm systems in our application may be made:

a) Alarm system failure rates are usually very low, in our example 1/4000 the protected system failure rate.

b) Alarm systems cannot be assigned critical failure importance equivalent to their protected functioning system.

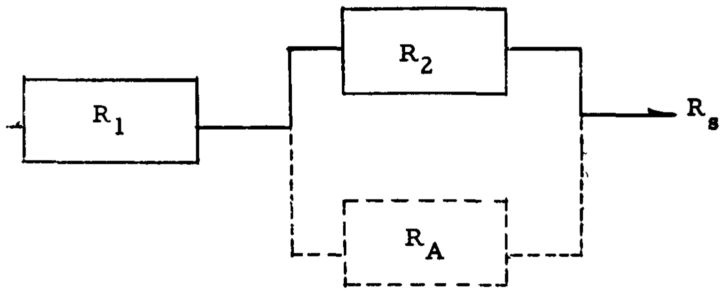
c) Alarm system failure rates should not be serially added to parent system failure rates for overall system reliability calculations.

d) Value of alarm systems increases as functional system operating time increases.

In consideration of the alarm discussion and the improbability of the necessity for launch during any short time after a correct alarm is given, during which system correction will be effected, alarm system failure rates in subsystems A, K, and L are eliminated in MTBF calculations.

The following block diagram and equations summarize the contribution of the alarm system to subsystem L of the LF. This may be considered typical of the other alarm systems.

Reliability Block Diagram:



Equation—Basic:

$$R = e^{-\lambda T}$$

R = Reliability (system or component)

λ = Failure rate (system or component)

T = Time of operation (system or component)

Equations—Specific Use:

$$R_{A2} = R_2 R_A + R_A Q_2 + R_2 Q_A$$

R_{A2} = Probability of success (reliability) of the parallel part of system

R_A = Alarm system reliability

R_2 = Reliability of protected subsystem L

Q_A, Q_2 = Failure probability of alarm and protected systems = $1 - R_A$, $1 - R_2$

$$R_s = R_1 \times R_{A2}$$

R_1 = Reliability of remainder of Launch Facility

R_s = Reliability of Launch Facility

$$R_s = e^{-\lambda_1 T}\left[e^{-\lambda_2 T} \times e^{-\lambda_A T} + e^{-\lambda_A T}\left(1 - e^{-\lambda_2 T}\right) + e^{-\lambda_2 T}\left(1 - e^{-\lambda_A T}\right)\right]$$

$$R_s = e^{-(\lambda_1+\lambda_A)T} + e^{-(\lambda_1+\lambda_2)T} - e^{-(\lambda_1+\lambda_2+\lambda_A)T} \qquad (1)$$

If an alarm system is not included:

$$R_s = e^{-(\lambda_1+\lambda_2)T} \tag{2}$$

If an alarm system is considered a series element:

$$R_s = e^{-\lambda_1 T} \cdot e^{-\lambda_2 T} \cdot e^{-\lambda_A T} = e^{-(\lambda_1+\lambda_2+\lambda_3)T} \tag{3}$$

<u>Relative System Reliability:</u>

using,

$$\lambda_A = 0.00127/10^6 \text{ hours}$$

$$\lambda_1 = 34.712/10^6 \text{ hours}$$

$$\lambda_2 = 4.809/10^6 \text{ hours}$$

<u>For T = 1 hour:</u>

$$R_s = e^{-(\lambda_1+\lambda_A)1} + e^{-(\lambda_1+\lambda_A)1} - e^{-(\lambda_1+\lambda_2\lambda_A)1} \tag{4}$$

$$R_s = e^{-(0.0000347)} + e^{-(0.0000395)} - e^{-(0.00003952)}$$

$$R_s = 0.9999653$$

$$R_s = e^{-(\lambda_1+\lambda_2)1} \tag{5}$$

$$R_s = e^{-(0.00003952)}$$

$$R_s = 0.99996056$$

$$R_s = e^{-(\lambda_1+\lambda_2+\lambda_A)1} \tag{6}$$

$$R_s = e^{-(0.000039522)}$$

$$R_s = 0.99996055$$

For T = 3 Months:

$$R_s = e^{-(0.0000347)2190} + e^{-(0.0000395)2190} - e^{-(0.00003952)2190} \tag{7}$$

$$R_s = 0.92661$$

$$R_s = e^{-(0.00003952)2190} \tag{8}$$

$$R_s = 0.91709$$

$$R_s = e^{-(0.000039522)2190} \tag{9}$$

$$R_s = 0.91708$$

As noted, the example system diagrammed shows approximately a one percent reliability increase at the end of a 90-day period over the same system without alarm protection or a system which considers alarms of equal importance to functioning system components.

The normal operating emergency water storage, designated subsystem D, falls into a different type of questionable area. In normal operation of the LCF installation this subsystem merely circulates water through the storage system, accepting a small amount of rejected heat at a brine-water heat exchanger. Circulation is provided mainly to maintain a minimal constant tank temperature. The small amount of heat picked up is rejected from the air-handling and brine chiller subsystem equipment and, in relation to their normally large heat loads, is inconsequential to satisfactory operation of those systems. In considering failures of this system and their relative importance to successful facility operation, it may be noted that the only failure which could possible have any effect on parent air-handling and brine chiller system operation is failure at the heat exchanger. The probability of this occurrence is so slight as to be inconsequential to our calculations. Thus, although this is a normal operating system, its function during normal operation is not essential to LCF operation and its failure is not critical to LCF operation continuance. Therefore, its failure rate should not be contributory to the normal subsystems failures in determining critical MTBF predictions. The LCF(SRCC) and LCF(LCC) normal subsystems should be redefined to include the following minor essential subsystems for MTBF calculations:

Air Handing-Support Building

Packaged Brine Chiller

Air Handling

Exhaust Air System

Control Air Supply

The difference, as indicated, is in the elimination of subsystem D, normal operating emergency water storage, from the tabulation.

Figure 4 is a schematic operational diagram of the environmental control system of the Launch Control Facility, type LCC. The method of reduction of this system to its individual reliability failure rate components is typical of the method used for the other major subsystems, LF and LCF (SRCC). The control systems are reduced to their major operational blocks as shown in Figure 5. The operational blocks reduced in Figure 6 to subsystem reliability blocks indicate a series relationship among the subsystems, in that if any one of the subsystems fails, the complete LCF function fails. The water storage tank subsystem does not appear in this diagram for reasons already noted, although it does appear in the operational diagram (Figure 5) as a definite operating function. Each of the minor subsystem components has been arranged as indicated in Figures 6a through 6e, has been assigned failure rates as tabulated in Exhibit I, and has been added to obtain minor subsystem totals. The symbols used in Figures 6a through 6e are detailed in Exhibit I. Each of the five minor subsystem failure rate totals has been added to obtain the predicted LCF totals and the resulting MTBF shown at the bottom of Figure 6.

Air Handing-Support Building

Packaged Brine Chiller

Air Handling

Exhaust Air System

Control Air Supply

The difference, as indicated, is in the elimination of subsystem D, normal operating emergency water storage, from the tabulation.

Figure 4 is a schematic operational diagram of the environmental control system of the Launch Control Facility, type LCC. The method of reduction of this system to its individual reliability failure rate components is typical of the method used for the other major subsystems, LF and LCF (SRCC). The control systems are reduced to their major operational blocks as shown in Figure 5. The operational blocks reduced in Figure 6 to subsystem reliability blocks indicate a series relationship among the subsystems, in that if any one of the subsystems fails, the complete LCF function fails. The water storage tank subsystem does not appear in this diagram for reasons already noted, although it does appear in the operational diagram (Figure 5) as a definite operating function. Each of the minor subsystem components has been arranged as indicated in Figures 6a through 6e, has been assigned failure rates as tabulated in Exhibit I, and has been added to obtain minor subsystem totals. The symbols used in Figures 6a through 6e are detailed in Exhibit I. Each of the five minor subsystem failure rate totals has been added to obtain the predicted LCF totals and the resulting MTBF shown at the bottom of Figure 6.

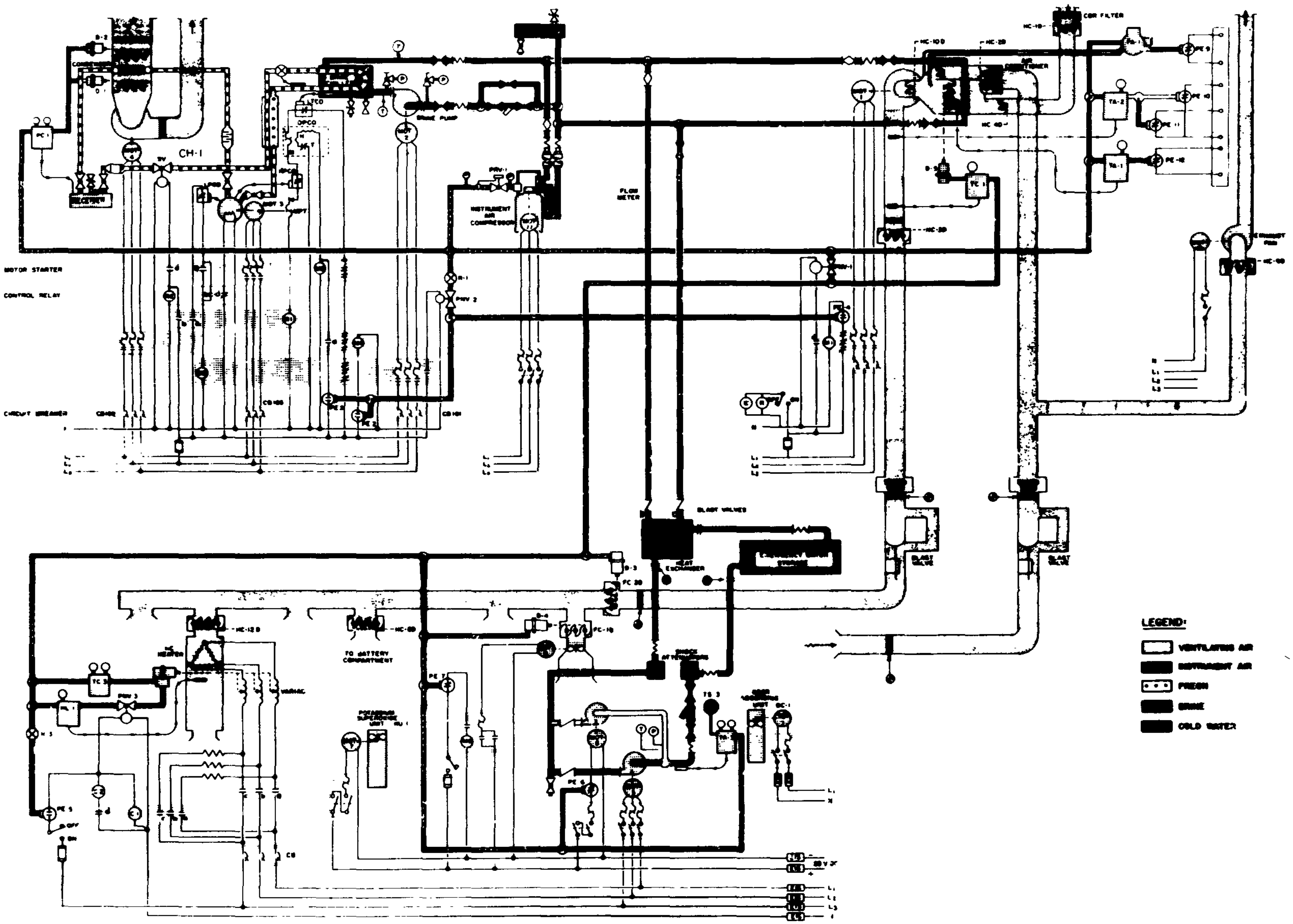


Figure 4. LCF Environmental Control System Schematic

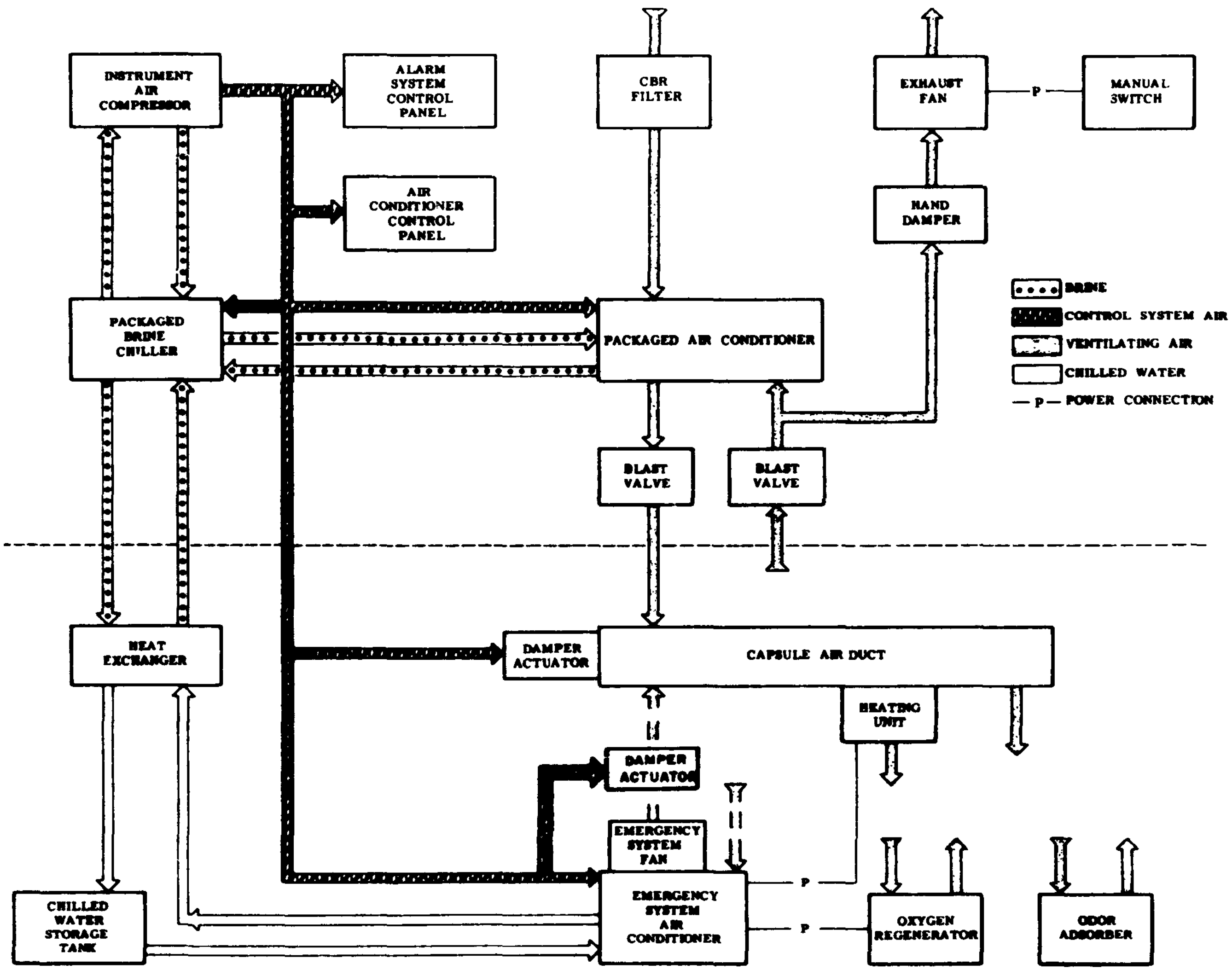
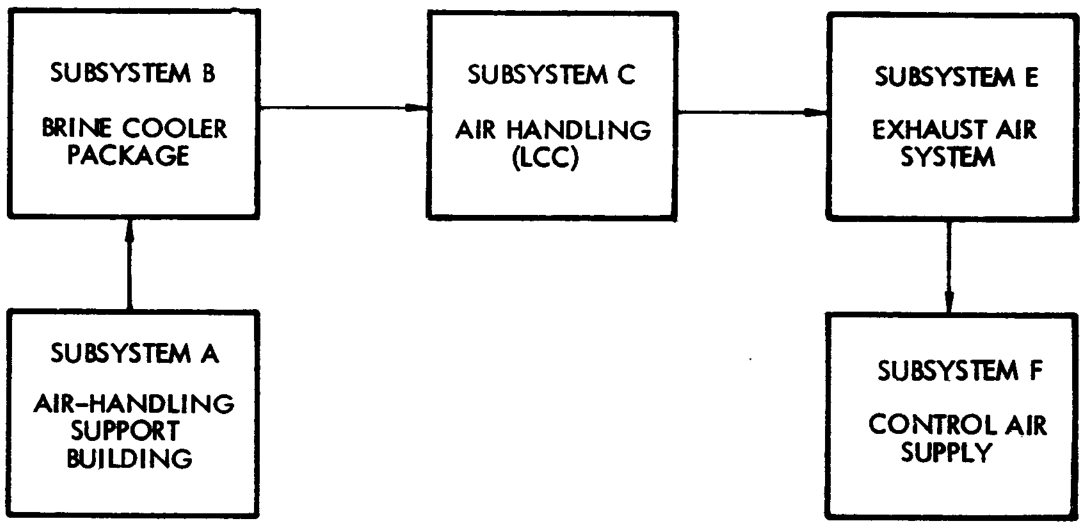


Figure 5. LCF Environmental Control System Operational Block Diagram



PREDICTED FAILURE:

PER 10^6 HOURS = 48.7732 = TOTAL = 20,503 HOURS MTBF FOR LCF (LCC) SYSTEM

Figure 6. LCF(LCC) Block Diagram

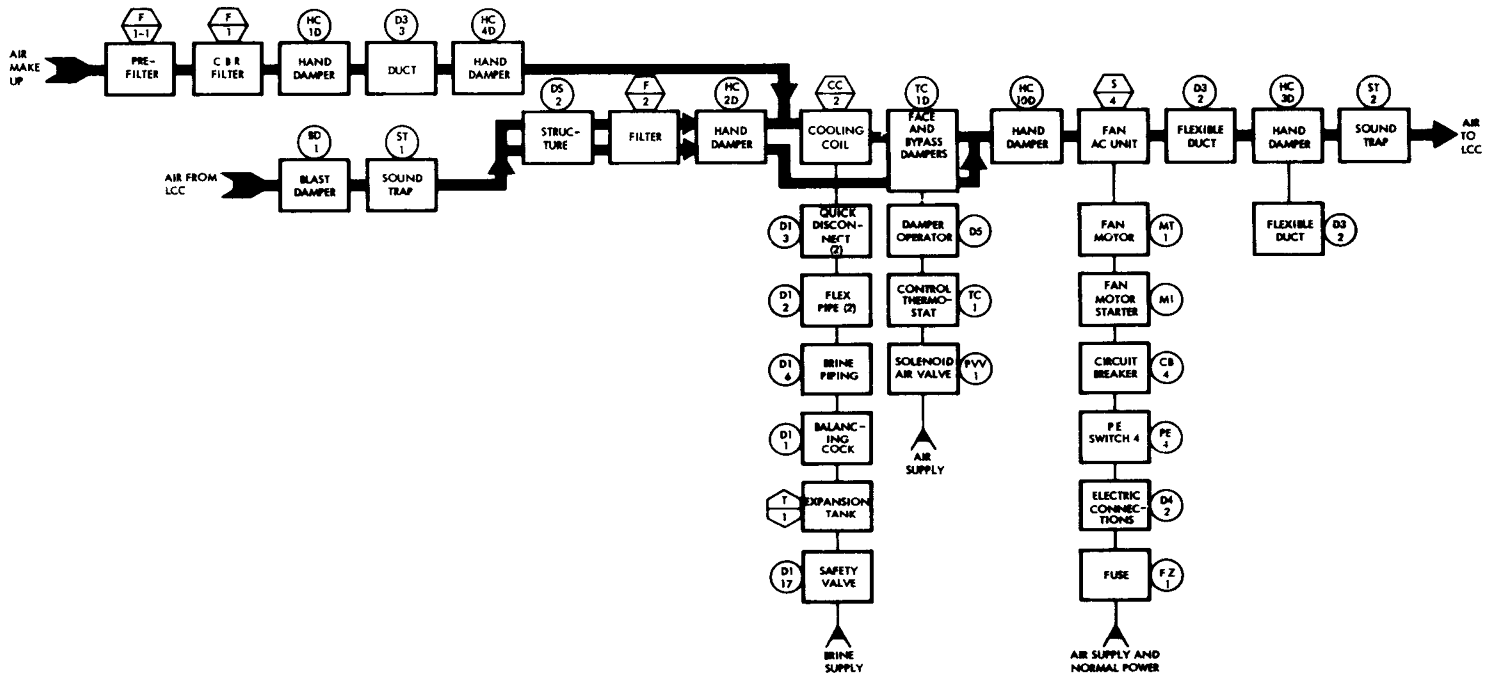


Figure 6a. Subsystem A Block Diagram

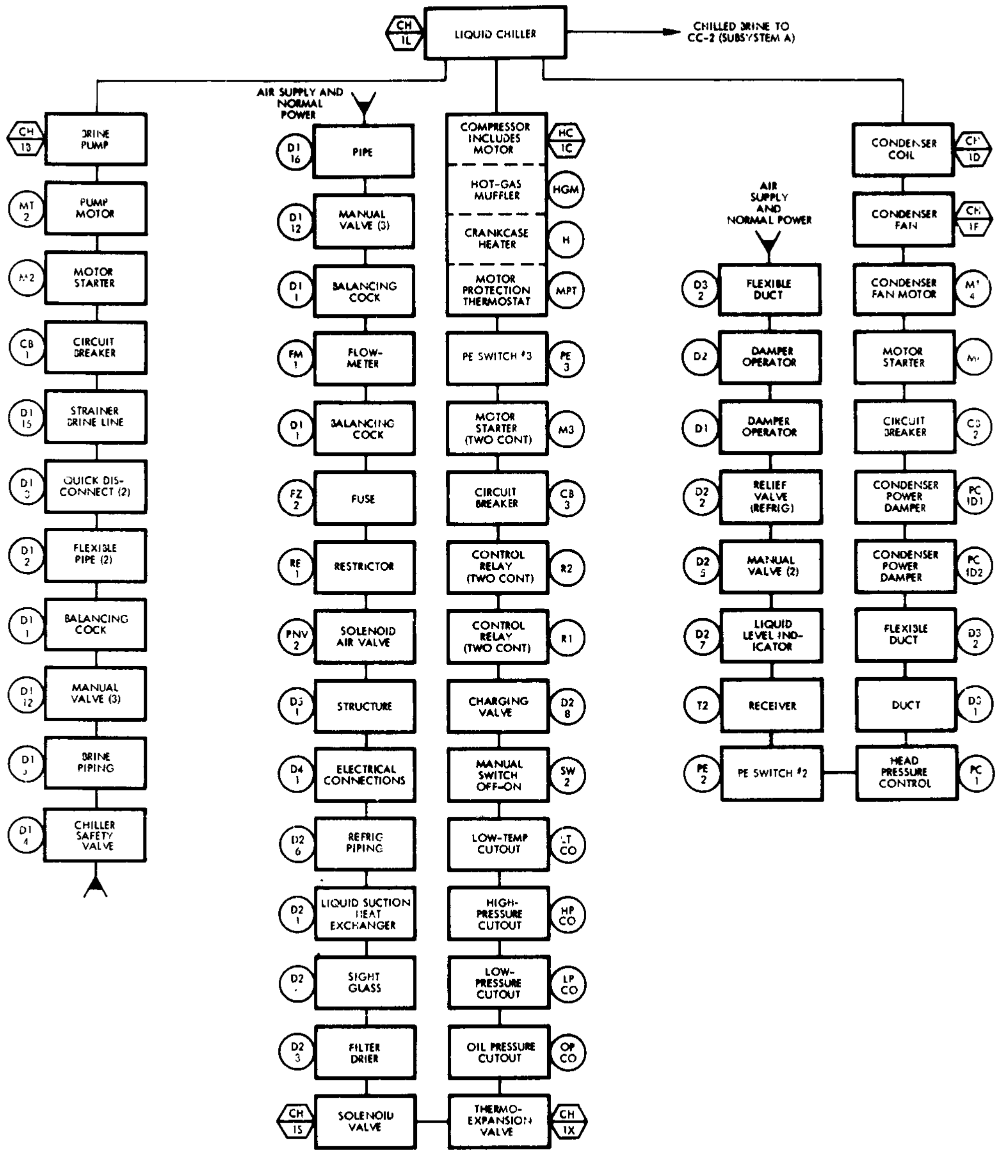


Figure 6b. Subsystem B Block Diagram

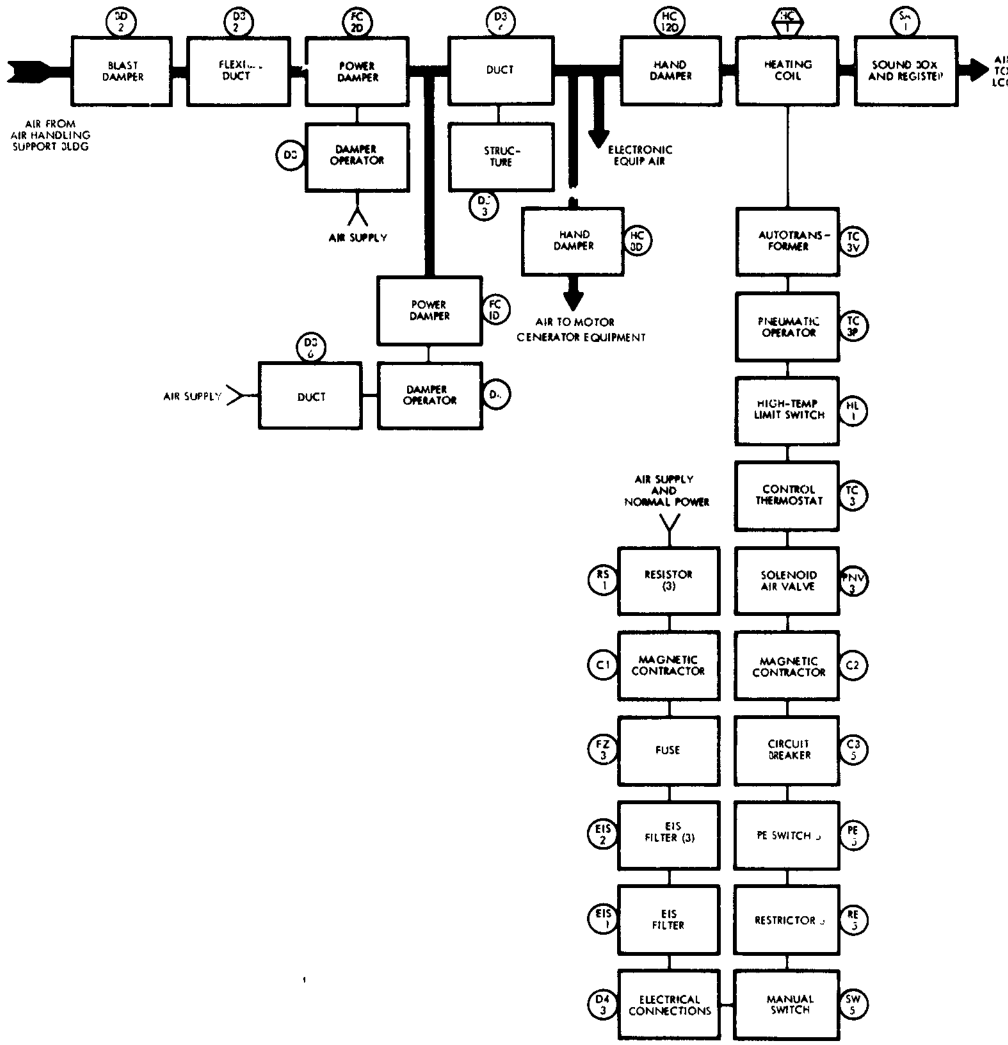


Figure 6c. Subsystem C Block Diagram

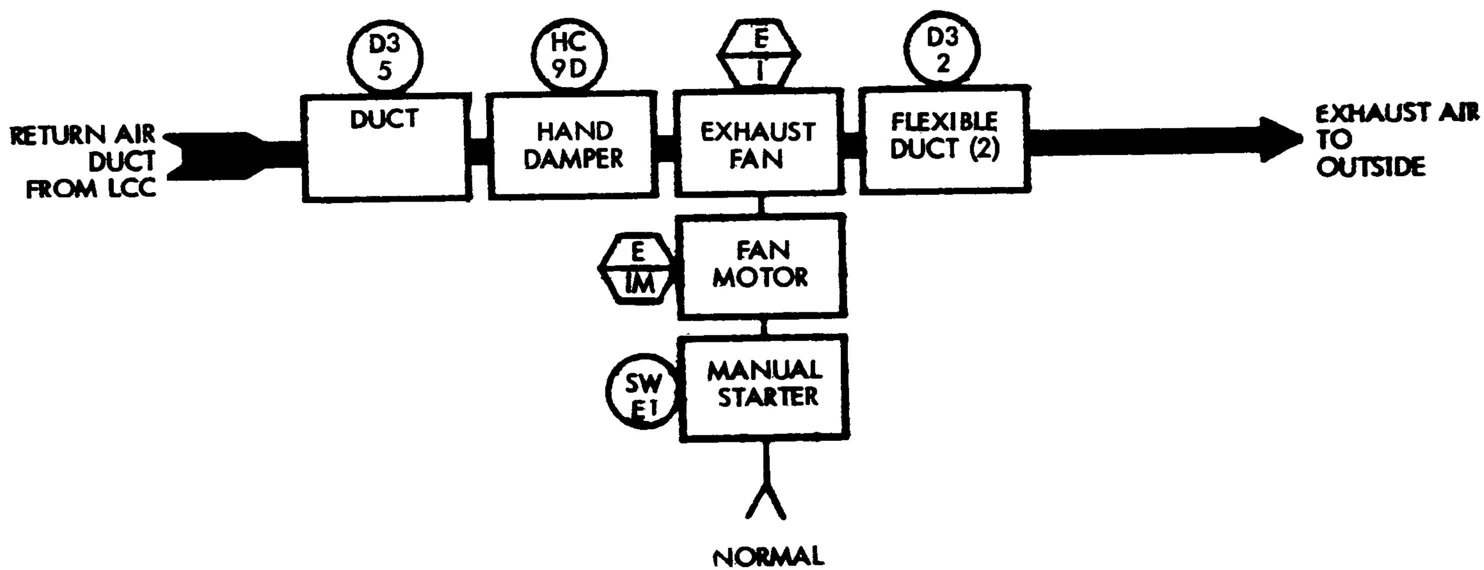


Figure 6d. Subsystem E Block Diagram

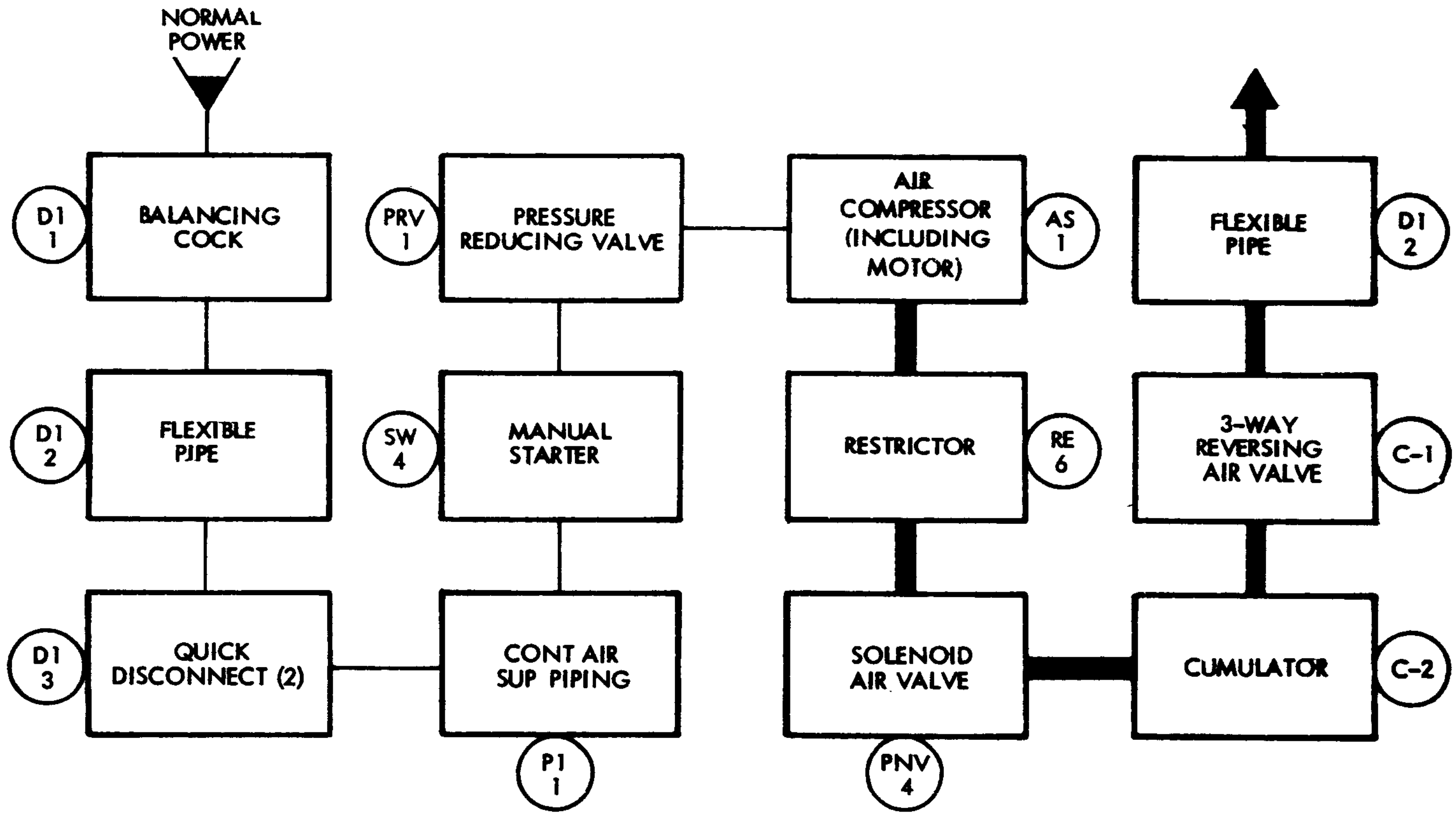


Figure 6e. Subsystem F Block Diagram

Component Failure Rate Summary

Exhibit I presents a summary by component of the failure rates quoted in the AAF report, Reference 1, corrected to April 1962; data compiled by Reference 2; and data determined by STL based upon both the Reference 1 report and corrected April data. Individual sheets are compiled by subsystem letter designation and title and include only the components required for the particular subsystem. Symbols used are those devised by the originating contractor for components, quantities, and part numbers as listed. The components listed by Holladay and Westcott, Reference 2, are equivalent components as indicated in their report. The lone column subtitled AAF-April lists the updated failure ratc differences between November 1961 and April 1962 for AAF data. The final STL columns show the STL evaluation of the AAF November and April data. The source and K factor column refers to the basic source for the STL rates and the use modification factor used to produce the listed STL rate.

The Comments column reflects reasons for the STL-predicted failure rates, comparison levels, basic data sources, conflict with AAF or Holladay and Westcott failure data, and other pertinent information. No attempt is made in these tabulations to determine the system component requirements, correct the nomenclature, or arbitrarily update failure rates. The STL-listed failure rates are the best predictions of unsuccessful equipment operation based upon currently available data.

SUBSYSTEM A: AIR HANDLING—SUPPORT BUILDING
FACILITY: LCF(SRCC) NORMAL

AMERICAN AIR FILTER November - 61					HOLLADAY AND WESTCOTT November - 61			SPACE TECHNOLOGY LABORATORIES, INC.			
Symbol	Component Name	Quantity	AAF Part No.	AAF Fail Rate Per 10^6 Hr	Corresponding Component	H and W Fail Rate Per 10^6 Hr	AAF April—Fail Per 10^6 Hr	STL Nov—Fail Per 10^6 Hr	Source and K Factor	STL April—Fail Per 10^6 Hr	Comments
F1-1	Pre-Filter	1	MAF 86443	0.00224	Mechanical Filter	0.3000	---	0.00224	AAF	0.00224	Estimated - Filters are to be
F-1	CBR Filter	1	MAF 85587	0.00224	Mechanical Filter	0.3000	---	0.00224	AAF	0.00224	changed every (3) months
HC-1D	Hand Damper	1	MDF 86193	0.0137	Structure Sections	1.0000	---	0.13700	STL	0.13700	Same as power damper
D3-3	Duct	1 Lot	MDH 87612	0.0001	Blower Duct	0.5125	---	0.10000	STL	0.10000	Estimate for ducts
HC-4D	Hand Damper	2	MAF 85628	0.0274	Structure Sections	2.0000	---	0.27400	STL	0.27400	Same as power damper
BD-1	Blast Damper - 24" Air	1 NIC		---							
ST-1	Sound Trap	1	MDF 86426	0.001	Baffles	1.0000	---	0.00100	STL	0.00100	Estimate for structure
D5-2	Structure	2 Lot		0.0002	Structure Sections	2.0000	---	0.00200	STL	0.00200	Estimate for structure
F-2	Filter	2	MAF 85264	0.00448	Mechanical Filter	0.6000	---	0.00448	STL	0.00448	Estimated - Filters are to be changed every (3) months
HC-2D	Hand Damper	2	MAF 87087	0.0274	Structure Sections	2.0000	---	0.27400	STL	0.02740	Same as power damper
TC-1D	Face and Bypass Dampers	2	MAF 87088	0.274	Structure Sections	2.0000	---	0.27400	AAF	0.27400	---
D-5	Damper Operator	2	MPL 86441	1.08	Electrical Motor	0.6000	---	0.07860	M/H	0.07860	Cylinder (air) not an electric motor
TC-1	Control Thermostat	2	MPL 85321	0.200	Thermostats	0.1200	---	0.77440	M/H	0.77440	---
PNV-1	Solenoid Air Valve	2	MPL 85231	0.00004	Solenoid Valves	22.0000	---	0.05000	M/H	0.05000	Derated for cycling only
CC-2	Cooling Coil	2	MBF 86640	0.032	Lines and Fittings	0.4000	---	0.20000	STL	0.20000	Estimate for cooling coil (pipe)
D1-3	Quick Disconnect	4	MBL 85436	0.114	Flexible C Plugs	2.7500	---	0.11400	AAF	0.11400	Snap-Tite data
D1-2	Flexible Pipe	4	MBF 86419	0.040	Hoses	8.0000	---	0.80000	STL	0.80000	Estimate for flexible pipe
D1-6	Brine Piping	2 Lot	CU Type K	0.002	Lines and Fittings	0.4000	---	0.20000	STL	0.20000	Estimate for pipe
D1-1	Balancing Cock	2	MRL 86622	0.040	Transfer Valves	1.0000	---	0.04000	AAF	0.04000	Estimated (Ref. AAF)
T-1	Expansion Tank	1	MBG 85227	0.001	Tanks	0.1500	---	0.00100	STL	0.00100	Estimate for structures
D1-17	Safety Valve	1	MRG 85228	0.050	Vent and Relief Valves	5.7000	---	0.05000	AAF	0.05000	Vendor data
HC-10D	Hand Damper	2		0.129	Structure Section	2.0000	---	0.27400	STL	0.27400	Same as power damper
S-4	Fan AC Unit	2	MAF 86627	0.0216	Exhaust Fans	0.4500	---	0.02160	STL	0.02160	Clarage fan data
MT-1	Fan Motor (3 hp)	2		7.92	Electrical Motor	0.6000	---	3.96000	STL-50%	3.96000	Derating of Reliance Electric data
M-1	Fan Motor Starter	2	MEL 85155	0.000492	Contactors	0.5000	---	0.00049	AAF	0.00049	Allen-Bradley data
CB-4	Circuit Breaker	2	MEF 85285	0.00366	Circuit Breaker	0.2750	---	0.00366	AAF	0.00366	ITE data (derated AAF)
PE-4	P.E. Switch No. 4	2	MPL 85235	0.0001	Switches	0.2800	---	0.02400	M/H	0.02400	
D4-2	Electric Connections	2 Lot	(Piping)	0.020	Cable Assemblies	0.0400	---	0.00020	STL	0.00020	STL estimate electric conduit
FZ-1	Fuse	2	MS 90088-23	0.600	Fuses	1.0000	---	0.60000	AAF	0.60000	Vendor data (electr-tech.)
D3-2	Flexible Duct	2	MSS 87597-6	0.020	Flexible Hoses	4.0000	---	0.40000	STL	0.40000	Estimate for flexible duct
HC-3D	Hand Damper	2	MDF 86135	0.0274	Structure Section	2.0000	---	0.27400	STL	0.27400	Same as power damper
ST-2	Sound Trap	1	MDF 86410	0.001	Baffles	1.0000	---	0.00100	STL	0.00100	Estimate for structures
TA-1	Thermostat	2	MPL 85321	0.000834	Thermostats	0.1200	---	0.19360	M/H		---
PE-12	P.E. Switch No. 12	2	MPL 85236	0.0002	Switches	0.2800	---	0.04800	M/H	0.03800	---
TA-2	Thermostat	2	MPL 85334	0.000834	Thermostats	0.1200	---	0.19360	M/H	0.19360	---
PE-10	P.E. Switch No. 10	2	MPL 85236	0.0002	Switches	0.2800	---	0.04800	M/H	0.04800	---
PE-11	P.E. Switch No. 11	2	MPL 85235	0.0002	Switches	0.2800	---	0.04800	M/H	0.04800	---
FA-1	Flow Controller	2	MPL 85315	0.0011	Flow and Press Regulator	4.2800	---	0.01500	M/H	0.01500	Not a pressure regulator
PE-9	P.E. Switch No. 9	2	MPL 85236	0.0002	Switches	0.2800	---	0.04800	M/H	0.04800	---
D3-2	Flexible Duct	1	MAG 87597-7	0.010	Flexible Hoses	2.0000	+0.0100	0.20000	STL	0.40000	Estimate for flexible duct (STL)
D1-8	Drain Valve	1		0.0146	Transfer Valve	0.5000	-0.0146	0.02920	STL	---	Estimate for manual valve

SUBSYSTEM A: AIR HANDLING—SUPPORT BUILDING
FACILITY: LCF(LCC) NORMAL

AMERICAN AIR FILTER November - 61					HOLLADAY AND WESTCOTT November - 61			SPACE TECHNOLOGY LABORATORIES, INC			
Symbol	Component Name	Quantity	AAF Part No	AAF Fail Rate Per 10^6 Hr	Corresponding Component	H and W Fail Rate Per 10^6 Hr	AAF April—Fail Per 10^6 Hr	STL Nov—Fail Per 10^6 Hr	Source and K Factor	STL April—Fail Per 10^6 Hr	Comments
F1-1	Pre-Filter	1	MAF 86443	0.00224	Mech Filter	0.3000	---	0.00224	AAF	0.00224	Est. filters are to be changed every 3 months
F-1	CBR Filter	1	MAF 85587	0.00224	Mech. Filter	0.3000	---	0.00224	AAF	0.00224	
HC-1D	Hand Damper	1	MDF 86193	0 01370	Structure Section	1.0000	---	0.13700	AAF	0.13700	Same as power damper
D3-3	Duct	1 Lot	MDH 87612	0 00010	Blower Duct	0 5125	---	0 10000	STL	0.10000	Estimate for duct
HC-4D	Hand Damper	1	MAF 85628	0 01370	Structure Section	0.3300	---	0.13700	AAR	0.13700	Same as power damper
BD-1	Blast Damper - 24" Air	1 NIC									
ST-1	Sound Trap	1	MDF 86426	0.00100	Baffle	1.0000	---	0.00100	STL	0.00100	Estimate for structure
D5-2	Structure	1 Lot		0.00010	Structure Section	1.0000	---	0.00100	STL	0.00100	Estimate for structure
F-2	Filter	1	MAF 85264	0.00224	Mech. Filter	0.3000	---	0.00224	AAR	0.00224	Estimate filters are to be changed every 3 months
HC-2D	Hand Damper	1	MAF 87087	0 01370	Structure Section	1.0000	---	0.13700	STL	0.13700	
TC-1D	Face and Bypass Dampers	1	MAF 87088	0.13700	Structure Section	1.0000	---	0.13700	AAF	0.13700	Same as power damper
D-5	Damper Operator	1	MPL 86441	0.5400	Electric Motor	0.3000	---	0.03930	M/H	0.03930	Cylinder (Air) not an electric motor
TC-1	Control Thermostat	1	MPL 85321	0.10000	Thermostat	0.0600	---	0 38720	M/H	0.38720	---
PNV-1	Solenoid Air Valve	1	MPL 85231	0.00002	Solenoid Valve	11.0000	---	0.02500	M/H	0.02500	Derated for cycling only
CC-2	Cooling Coil	1	MBF 86640	0 01600	Lines and Fittings	0.2000	---	0.10000	STL	0.10000	STL estimates cool. coil (pipe)
D1-3	Quick Disconnect	2	MBL 85436	0 05720	Flexible Coupling	1.3750	---	0.05720	AAF	0.05720	Snap-Tite data
D1-2	Flexible Pipe	2	MBF 86419	0.02000	Hoses	4.0000	---	0.40000	STL	0.40000	STL estimate flexible pipe 0.2
D1-6	Brine Piping	1	CU TYPE K	0 00100	Lines and Fitting	0.2000	---	0 10000	STL	0.10000	STL estimate pipe 0.1
D1-1	Balancing Cock	1	MRL 86622	0.02000	Transfer Valve	0.5000	---	0.02000	AAF	0.02000	AAF estimate vendor data
T-1	Expansion Tank	1	MBG 85227	0.00100	Tanks	0.1500	---	0.00100	STL	0.00100	STL estimate structure
D1-17	Safety Valve	1	MRG 85228	0 0500	Vent and Relief Valve	5.7000		0.05000	AAF	0.05000	Watts Regulator Co. data
HC-10D	Hand Damper	1		0 06450	Structure Section	1.0000	---	0.13700	STL	0.13700	STL estimate all dampers
S-4	Fan AC Unit	1	MAF 86627	0 01080	Exhaust Fan	0.2250	---	0.01080	AAF	0.01030	Clarage fan data
MT-1	Fan Motor (3 HP)	1		3.96000	Electric Motor	0.3000	---	1.98000	STL-50%	1 98000	Derating of Reliance Electric data
M-1	Fan Motor Starter	1	MEL 85155	0 00025	Contractor	0.2500	---	0.00025	AAF	0.00025	Allen-Bradley data (switch and surge coil)
CB-4	Circuit Breaker	1	MEF 85285	0.00183	Circuit Breaker	0.1375	---	0.00183	AAF	0.00183	AAF derates ITE
PE-4	P.E. Switch No 4	1	MPL 85235	0 00005	Switches	0 1400	---	0.02400	M/H	0.02400	---
D4-2	Electric Connections	1 Lot		0.01000	Cable Assemblies	0.0200	---	0.00010	STL	0.00010	STL estimate electric conduit
FZ-1	Fuse	1	MS 90088-23	0.30000	Fuse	0.5000	---	0.30000	AAF	0.30000	Electro-Tech data
D3-2	Flexible Duct	2	MSS 87597-6	0.02000	Hose	4.0000	0.0100	0.40000	STL	0.20000	STL estimate flexible duct
HC-3D	Hand Damper	1	MDF 86135	0 01370	Structure Section	1.0000	---	0.13700	STL	0.13700	STL estimate all dampers
ST-2	Sound Trap	1	MDF 86410	0.00100	Baffle	1.0000	---	0.00100	STL	0.00100	STL estimate structures
TA-1	Thermostat	1	MPL 85321	0.00042	Thermostat	0.0600	---	0.09680	M/H	0.09680	---
PE-12	P.E. Switch No. 12	1	MPL 85236	0.00010	Switches	0 1400	---	0.02400	M/H	0.02400	---
TA-2	Thermostat	1	MPL 85334	0 00042	Thermostat	0.0600	---	0.09680	M/H	0.09680	---
PE-10	P E Switch No 10	1	MPL 85236	0 00010	Switches	0.1400	---	0.02490	M/H	0.02400	---
PE-11	P.E Switch No 11	1	MPL 85235	0 00010	Switches	0 1400	---	0.02400	M/H	0.02400	---
FA-1	Flow Controller	1	MPL 85315	0.00055	Flow and Press. Regulator	2 1400	---	0.00758	M/H	0.00750	Not a pressure regulator
PE-9	P E Switch No 9	1	MPL 85236	0.00010	Switches	0.1400	---	0 02400	M/H	0.02400	---
D1-8	Drain Valve	1		0 01460	Transfer Valve	0.5000	-0.0146	0 02920	STL	---	---

SUBSYSTEM B: PACKAGED BRINE CHILLER
FACILITY: LCF(SRCC) NORMAL

AMERICAN AIR FILTER November - 61					HOLLADAY AND WESTCOTT November - 61			SPACE TECHNOLOGY LABORATORIES, INC.			
Symbol	Component Name	Quantity	AAF Part No.	AAF Fail Rate Per 10^6 Hr	Corresponding Component	H and W Fail Rate Per 10^6 Hr	AAF April—Fail Per 10^6 Hr	STL Nov—Fail Per 10^6 Hr	Source and K Factor	STL April—Fail Per 10^6 Hr	Comments
CH-1L	Liquid Chiller	2	MRG 85606	0.430	Heat Exchangers	30.0000	---	0.4300	AAF	0.43000	AAF derates AAF data
CH-1B	Brine Pump and Seal	2	MRG 85086	3.17	Pumps	27.0000	-0.03	13.5340	STL	13.53400	AAF - excessive derating
MT-2	Pump Motor (3 hp)	2		5.78	Electric Motor	0.6000	+2.140	3.96000	STL-50%	3.96000	Derating of Reliance Elec. Co. data
M-2	Motor Starter	2	MEL 85155	0.000492	Contactor	0.5000	---	0.000492	AAF	0.00049	Allen-Bradley data (switch & surge coil)
CB-1	Circuit Breaker	2	MEG 85237	0.00366	Circuit Breaker	0.2750	---	0.00366	AAF	0.00366	AAF derates ITE
D1-15	Strainer Brine Line	2	MBG 85211	0.320	Mechanical Filters	0.6000	---	0.20000	STL	0.20000	Metal screen estimate
D1-3	Quick Disconnects	4	MBG 85638	0.114	Flexible Coupling	2.7500	---	0.1140	AAF	0.11400	Snap-Tite data
D1-2	Flexible Pipe	4	MBG 86418	0.040	Hoses	8.0000	---	0.80000	STL	0.80000	STL estimate flexible pipe 0.2
D1-12	Manual Valve	5	MSS 87775	0.0730	Shut-Off Valve	32.5000	+0.0146	0.2910	STL	0.34920	Water valves - derate AAF (Mueller) x 2
D1-5	Brine Piping	2 Lots	CU Type K	0.002	Line and Fittings	0.4000	---	0.2000	STL	0.20000	STL estimate for pipe 0.1
D1-4	Chiller Safety Valve	2	MBG 85012	0.100	Vent and Relief Valves	11.400	---	0.1000	AAF	0.10000	Watts Regulator Co. data
HGM	Hot Gas Muffler	2	MRG 85082	0.159	Baffles	2.0000	---	0.1590	AAF	0.15900	Carrier Letter July 61 to AAF
CH-1C	Compressor Incl Motor	2			Compressor (Boeing)	12.0000					
H	Crankcase Heater	2	MRG 85000	10.10	Electric Motors	0.2200	---	10.1000	AAF	10.1000	STL estimate concur with AAF
MPT	Motor Protection Therm	2			Heater Element	0.0200					
PE-3	P.E. Switch No. 3	2	MPL 85235	0.0001	Thermostats	0.0400					
M-3	Motor Starter 2 Contacts	2	MEG 85179	0.000944	Switches	0.2800	---	0.04800	M/H	0.04800	---
					Contactor	1.000	---	0.000944	AAF	0.00094	AAF derates Allen-Bradley
CB-3	Circuit Breaker	2	MEG 85238	0.00366	Circuit Breaker	2.7500	---	0.00366	AAF	0.00366	AAF derates ITE
R-2	Control Relay 2 Contacts	2	MEG 86265	0.000464	G.P. Relays	1.0000	---	0.00046	AAF	0.00046	AAF derates Allen-Bradley
R-1	Control Relay 2 Contacts	2	MEL 85165	0.000464	G.P. Relay	1.0000	---	0.00046	AAF	0.00046	AAF derates Allen-Bradley
SW-2	Manual Switch Off-On	2	MEL 85590	0.00302	Toggle Switch	0.1200	---	0.0030	AAF	0.00300	AAF derates Allen-Bradley
LTCO	Low Temperature Cutout	2	MEL 85178	0.000626	Contactor	0.5000	---	0.00063	AAF	0.00060	AAF derates Allen-Bradley
HPCO	High Pressure Cutout	2	MEG 86262	0.000626	Contactor	0.5000	---	0.00063	AAF	0.00060	AAF derates Allen-Bradley
LPCO	Low Pressure Cutout	2		0.00314	Contactor	0.5000	---	0.0031	AAF	0.00310	AAF derates Allen-Bradley
OPCO	Oil Pressure Cutout	2	MEG 85244	0.810	Contactor	0.5000	---	0.8100	AAF	0.81000	Penn. Cont. Inc., data
D1-1	Balancing Cock	2	MRL 86623	0.040	---	---	+0.0400	---	---	0.04000	STL estimate values
FM-1	Flow Meter	1	MAF 85361	0.031	---	---	+0.0310	---	---	0.03100	AAF derates Brooks Instrument
D1-1	Balancing Cock	1	MRL 87443	0.020	---	---	+0.0200	---	---	0.02000	STL estimate valves
D1-12	Manual Valve	3	MSS 87681	0.0438	---	---	+0.0438	---	---	0.17460	Water valve derate AAF (Mueller) x 2
D1-16	Pipe	1 Lot	CU Type K	0.001	---	---	+0.0010	---	---	0.10000	STL estimate for pipe 0.1
CH-1X	Thermo Expansion Valve	2	MRG 85013	3.88	Control Valve	17.0000	---	3.8800	AAF	3.88000	ALCO valve data
CH-1S	Solenoid Valve	2	MRG 85248	0.348	Solenoid Valve	22.0000	---	0.34800	AAF	0.34800	AAF derates ALCO valve
D2-3	Filter Drier	2	MRG 85249	0.46	Mechanical Filter	0.6000	---	0.4600	AAF	0.46000	Est. by AAF - Letter from vendor
D2-4	Sight Glass	2	MRG 85288	0.00434	Sight Glass (AAF)	0.0043	---	0.00434	AAF	0.00434	Vendor data
D2-1	Liquid Suction Heat Exch	2	MRG 85122	0.002	Heat Exchangers	30.0000	---	0.2000	STL	0.40000	Estimate for heat exchange
D2-6	Refrigerant Piping	2 Lots		0.002	Lines and Fitting	0.4000	---	0.2000	STL	0.20000	Estimate for pipe
D4-1	Electrical Connections	2 Lots		0.020	Cable Assemblies	0.0400	---	0.0002	STL	0.00020	Estimate for electrical connections
D5-1	Structure	2 Lots		0.0002	Structure Section	22.0000	---	0.00200	STL	0.00200	Estimate for structures
PNV-2	Solenoid Air Valve	2	MPL 85231	0.0004	Solenoid Valves	22.0000	---	0.05000	M/H	0.05000	Derated for cycling only
RE-1	Restrictor	4	MPL 85233	0.0000006	Restrictors	1.1800	+0.0002	0.0002	STL	0.00040	AAF shows (2) should be (4)
D2-8	Charging Valve	2	MHF 86023	0.0007	Valves	10.2000	---	0.00070	AAF	0.00070	Vendor data

SUBSYSTEM B PACKAGED BRINE CHILLER

FACILITY: LCF(SRCC) NORMAL (Continued)

	AMERICAN AIR FILTER November-61				HOLLADAY AND WESTCOTT November-61			SPACE TECHNOLOGY LABORATORY, INC.			
Symbol	Component Name	Quantity	AAF Part No.	AAF Fail Rate Per 10^6 Hr	Corresponding Component	H and W Fail Rate Per 10^6 Hr	AAF April-Fail Per 10^6 Hr	STL Nov-Fail Per 10^6 Hr	Source and K Factor	STL April-Fail Per 10^6 Hr	Comments
RE-1	Restrictor	1	MPL 85233	0.0000	Restrictor	0.00020	0.5900	---	STL	0.00020	AAF shows (1) SH. BE (2)
PNV-2	Solenoid Air Valve	1	MPL 85231	0.0000	Solenoid Valve	0.02500	11 0000	---	M/H	0.02500	Derated for cycling only
D2-8	Charging Valve	1	MBF 86023	0.00035	Valves	0.00035	5.1000	---	AAF	0.00035	Low usage valve
FZ-2	Fuse	1	MS 90088-27	0.30000	Fuse	0.30000	0.5000	---	AAF	0.30000	Electro-technical data
FZ-2	Fuse	2	MS 90088-27	0.600	Fuses	0.6000	1.0000	---	AAF	0.60000	Electro-technical data
CH-1D	Condenser Coil	2	MRG 85069	0.214	Air Cooled Cond (Boeing)	0.20000	1.4060	---	STL	0.20000	Estimate for coils
CH-1F	Condenser Fan	2	MRG 86635	0.0216	Exhaust Fans	0.02160	0.4500	---	AAF	0.02160	
MT-4	Condenser Fan Motor (7 1/2 HP)	2		15.14	Electric Motor	7.56000	0.6000	---	STL 50%	7.56000	Derating of Reliance Electric Data
M-4	Motor Starter	2	MEG 85180	0.000472	Contactor	0.000246	0.5002	---	AAF	0.00025	Allen-Bradley data switch and surge coil
CB-2	Circuit Breaker	2	MEG 85239	0.00366	Circuit Breaker	0.00366	0.2750	---	I.T.E.	0.00366	I.T.E
PC-1D-2	Condenser Power Damper	2	MRG 85066	0.274	Structure Section	0.27400	2.0000	---	AAF	0.27400	All dampers same (STL)
D-1	Damper Operator	2	MPL 86438	0.540	Electric Motors	0.05240	0.6000	---	M/H	0.05240	Cylinder (air) not an electric motor
D-2	Damper Operator	2	MPL 86439	0.540	Electric Motors	0.05240	0.600	---	M/H	0.05240	Cylinder (air) not an electric motor - λ same as D-1
D3-2	Flexible Duct	2	MAG 87597-10		Hoses	0.40000	4.0000	---	STL	0.40000	STL estimate flexible duct 0.2
D3-1	Duct	2 Lots	MDH 87626	0.0002	Blower Ducts	0.20000	1.025	---	STL	0.20000	STL estimate duct 0.1
PC-1	Head Pressure Control	2	MPG 85232	0.1334	Flow and Pressure Regulator	0.33400	4.2800	---	M/H	0.38430	Not a flow regulator
PE-2	P.E. Switch No. 2	2	MPL 85235	0.0001	Switches	0.04800	0.2800	---	M/H	0.04800	----
T-2	Receiver	2	MRG 86207	0.002	Tanks	0.00100	0.3000	---	STL	0.00100	Estimate for structures
D2-7	Liquid Level Indicator and Switches Mech. Link	2	MRG 85245	2.12	Mech. Linkage (Prod. Engr)	2.12000	2.0000	---	AAF	2.12000	AAF derates Amer. Std. Cont. derate AAF (Mueller) x 2
D2-5	Manual Valve	4	MRG 85251	0.1164	Shut-off Valves	0.2328	26.0000	---	STL	0.23820	
D2-2	Relief Valve-Refrig.	2	MRG 85206	0.200	Relief Valves	2.6000	11.4000	+2.400	AAF	2.60000	AAF derates Henry valves
PC-1D-1	Condenser Pwr. Damper	2	MRG 86635	0.274	Structure Section	0.27400	2.0000	-0.046	STL	0.27400	All dampers are the same
D3-2	Flexible Duct	2	MAG 87597	0.020	Hoses	0.4000	4.0000	---	STL	0.40000	Estimate for duct

SUBSYSTEM B PACKAGED BRINE CHILLER
FACILITY: LF NORMAL, LCF(LCC) NORMAL

AMERICAN AIR FILTER November-61					HOLLADAY AND WESTCOTT November-61			SPACE TECHNOLOGY LABORATORY, INC.			
Symbol	Component Name	Quantity	AAF Part No.	AAF Fail Rate Per 10^6 Hr	Corresponding Component	H and W Fail Rate Per 10^6 Hr	AAF April-Fail Per 10^6 Hr	STL Nov-Fail Per 10^6 Hr	Source and K Factor	STL April-Fail Per 10^6 Hr	Comments
CH-1L	Liquid Chiller	1	MRG 85606	0 21500	Heat Exchanger	15.0000	---	0.21500	AAF	0.21500	AAF derates AAF data.
CH-1B	Brine Pump and Seal	1	MBG 85086	1.57000	Pump	13.5000	---	6.76700	AAF X.1	6.76700	Seal derated 0 1 vs 0.01 of Crane Company
MT-2	Pump Motor (1 hp)	1		2.890	Electric Motor	0.1100	+1.07	1.45000	STL-50%	1.98000	Derating of Reliance Electric data
M-2	Motor Starter	1	MEL 85155	0 00025	Contactor	0.2500	---	0.00025	AAF	0.00025	Allen-Bradley Data (switch and surge coil)
CB-1	Circuit Breaker	1	MEG 85237	0.00183	Circuit Breaker	0.1375	---	0.00183	AAF	0.00183	AAF derates ITE
C1-15	Strainer Brine Line	1	MBG 85211	0.16000	Mechanical Filter	0.3000	---	0.10000	STL	0.10000	Metal screen
D1-3	Quick Disconnects	2	MRG 85638	0.05720	Flexible Coupling	1.3750	---	0.05720	Snap-tite	0.05720	Vendor record and good AAF estimate
D1-2	Flexible Pipe	2	MBG 86418	0.02000	Hoses	4.0000	---	0.40000	STL	0.40000	STL estimate flexible pipe 0.2
D1-1	Balancing Cock	1	MRL 86623	0.02000	Transfer Valve	0.5000	---	0.02000	AAF	0.02000	STL estimate for valves
D1-12	Manual Valve	3	MSS 87775	0.04380	Shut-off Valve	19.5000	---	0.17460	STL	0.17460	Derated Mueller (AAF) x 2
DI-5	Brine Piping	1 Lot	CU TYPE K	0.00100	Line and Fittings	0.2000	---	0.10000	STL	0.10000	STL estimate for pipes
D1-4	Chiller Safety Valve	1	MBG 85012	0.05000	Vent and Rel. Valve	5.7000	---	0.05000	AAF	0.05000	
HGM	Hot Gas Muffler	1	MRG 85082	0.07950	Baffle	1.0000	---	0.07950	AAF	0.07950	Letter from Carrier Corp. June 1961 estimate by AAF.
CH- C	Compressor Includes Motor	1			Compressor (Boeing)	6.0000					
H	Crankcase Heater	1	MRG 85000	5.05000	Electric Motor	0.1100	---	5.05000	AAF	5.05000	STL estimate concur with AAF
MPT	Motor Protection Therm.	1			Heater Element	0.0100					
PE-3	P. E. Switch No. 3	1	MPL 85235	0.00005	Thermostat	0.0200					
M-3	Motor Starter Two Contacts	1	MEG 85179	0.00047	Switches Contactor	0.1400 0.5000	--- ---	0.02400 0.00050	M/H AAF	0.02400 0.00050	--- AAF derates Allen-Bradley
CB-3	Circuit Breaker	1	MEG 85238	0.00183	Circuit Breaker	0.1375	---	0.00183	AAF	0.00183	AAF derates ITE
R-2	Control Relay Two Contacts	1	MEG 86265	0.00023	G. P. Relay	0.5000	---	0.00023	AAF	0.00020	AAF derates Allen-Bradley
R-1	Control Relay Two Contacts	1	MEL 85165	0.00023	G. P. Relay	0.5000	---	0.00023	AAF	0.00020	AAF derates Allen-Bradley
SW-2	Manual Switch Off/On	1	MEL 85590	0.00151	Toggle Switch	0.0600	---	0.00150	AAF	0.00150	AAF derates Allen-Bradley
LTCO	Low Temperature Cutout	1	MEL 85178	0.00031	Contactor	0.2500	---	0.00030	AAF	0.00030	AAF derates Allen-Bradley
HPCO	High Pressure Cutout	1	MEG 86262	0.00031	Contactor	0.2500	---	0.00030	AAF	0.00030	AAF derates Allen-Bradley
LPCO	Low Pressure Cutout	1		0.00157	Contactor	0.2500	---	0.00160	AAF	0.00160	AAF derates Allen-Bradley
OPCO	Oil Pressure Cutout	1	MEG 85244	0.40500	Contactor	0.2500	---	0.40500	AAF	0.40500	Penn. Contractor Data
CH-1X	Thermo Expansion Valve	1	MRG 85013	1.94000	Control Value	8.5000	---	1.94000	ALCO	1.94000	ALCO letter July 1961
CH-1S	Solenoid Valve	1	MRG 85248	0.17400	Solenoid Valve	11.0000	---	0.17400	AAF	0.17400	ALCO data
D2-3	Filter Drier	1	MRG 85249	0.23000	Mechanical Filter	0.3000	---	0.23000	AAF	0.23000	Estimated by AAF- letter from vendor
D1-1	*Balancing Cock (LF only)	1	MRL 87442	0.02000	Transfer Valve	0.5000	---	0.02000	AAF	0.02000	Vendor data
D2-4	Sight Glass	1	MRG 85288	0.00217	Sight Glass	0.0022	---	0.00217	AAF	0.00217	Mueller Brass data and AAF estimate
D2-1	Liquid Suction Heat Exch.	1	MRG 85122	0.00100	Heat Exchanger	15.0000	---	0.21500	STL	0.20000	Estimate for heat exchanger
D2-6	Refrigerant Piping	1 Lot		0 00100	Line and Fitting	0.2000	---	0.10000	STL	0.10000	Estimate for pipes
D4-1	Electrical Connections	1 Lot		0 01000	Cable Assembly	0.0200	---	0.00010	STL	0.00010	Estimate for electrical connection
D5-1	Structure	1 Lot		0 00010	Structure Section	1.0000	---	0.00100	STL	0.00100	Estimate for structure section

SUBSYSTEM B: PACKAGED BRINE CHILLER

FACILITY: LF NORMAL, LCF(LCC) NORMAL (Continued)

AMERICAN AIR FILTER November - 61					HOLLADAY AND WESTCOTT November - 61			SPACE TECHNOLOGY LABORATORIES, INC.			
Symbol	Component Name	Quantity	AAF Part No.	AAF Fail Rate Per 10^6 Hr	Corresponding Component	H and W Fail Rate Per 10^6 Hr	AAF April—Fail Per 10^6 Hr	STL Nov—Fail Per 10^6 Hr	Source and K Factor	STL April—Hr Per 10^6 Hr	Comments
CH-1D	Condenser Coil	1	MRG 85069	0.10700	Air Cooled Cond. (Boeing)	0.7000	---	0.10000	STL	0.10000	Estimate for coil
CH-1F	Condenser Fan	1	MAG 86635	0.01080	Exhaust Fan	0.2250	---	0.01080	AAF	0.01080	
MT-4	Condenser Fan Motor ($7\frac{1}{2}$ hp)	1		7.57000	Electric Motor	0.3000	---	3.78000	STL-50%	3.78000	Derating of Reliance Electric data
M-4	Motor Starter	1	MEG 85180	0.00024	Contactor	0.2500	---	0.00024	AAF	0.00024	Allen Bradley data
CB-2	Circuit Breaker	1	MEG 85239	0.00183	Circuit Breaker	0.1375	---	0.00183	ITE	0.00183	ITE data
PC-1D-1	Condenser Power Damper was 117	1	MRG 86635	0.13700	Structure Section	1.0000	+0.020	0.13700	AAF	0.13700	All dampers 0.137
PC-1D-2	Condenser Power Damper	1	MRG 85066	0.13700	Structure Section	1.0000	---	0.13700	AAF	0.13700	All dampers 0.137
D-1	Damper Operator	1	MPL 86438	0.27000	Electric Motors	0.3000	---	0.02620	M/H	0.02620	Cylinder (air) not an electric motor
D-2	Damper Operator	1	MPL 86439	0.27000	Electric Motors	0.3000	---	0.02620	M/H	0.02620	Cylinder (air) not an electric motor λ same as D-1
D3-2	Flexible Duct	2	MAG 87597-10	0.020	Hose	2.0000	-0.010	0.20000	STL	0.20000	STL estimate for ducts
D3-1	Duct	1 Lot	MDH 87626	0.00010	Blower Duct	0.5125	---	0.10000	STL	0.10000	STL estimate for ducts
PC-1	Head Pressure Control	1	MPG 85232	0.06670	Flow and Press Regulator	2.1400	---	0.19200	M/H	0.19200	Not a flow regulator
PE-2	P.F. Switch No. 2	1	MPL 85235	0.00005	Switches	0.1400	---	0.02400	M/H	0.02400	---
T-2	Receiver	1	MRG 86207	0.00100	Tank	0.1500	---	0.00100	STL	0.00100	Estimate for structures
D2-7	Liquid Level Indicator and Switches Mech. Linkage	1	MRG 85245	1.06000	Mech Linkage (Prod Engr)	1.0000	---	1.0000	AAF	1.06000	AAF derates American Standard Control
D2-5	Manual Valve	2	MRG 85251	0.05820	Shut-Off Valve	13.0000	---	0.11640	AAF	0.11640	H&W data very unrealistic (AVCO) derate AAF x 2.0
D2-2	Relief Valve Refrigerant	1	MRG 85206	0.100	Relief Valve	5.7000	+1.20	0.10000	AAF	1.30000	H&W data very unrealistic (AVCO)
D3-2	Flexible Duct	1	MAG 87597-9	0.01000	Hose	2.0000	---	0.20000	STL	0.20000	Estimate for flexible duct
D1-16	Pipe	1 Lot	CU Type K				+0.001	---	STL	0.10000	STL - estimate for pipe

SUBSYSTEM C EXHAUST AIR SYSTEM

FACILITY: LCF(SRCC) NORMAL, LCF(LCC) NORMAL

AMERICAN AIR FILTER November - 61					HOLLADAY AND WESTCOTT November - 61			SPACE TECHNOLOGY LABORATORIES, INC			
Symbol	Component Name	Quantity	AAF Part No.	AAF Fail Rate Per 10^6 Hr	Corresponding Component	H and W Fail Rate Per 10^6 Hr	AAF April—Fail Per 10^6 Hr	STL Nov—Fail Per 10^6 Hr	Source and K Factor	STL April—Fail Per 10^6 Hr	Comments
BD-2	Blast Damper 24" Air	1 NIC		---							
D3-2	Flexible Duct	1	MAF 87289	0.01	Hoses	2.0000	---	0.20000	STL	0.20000	Estimate for flexible ducts
FC-2D	Power Damper	1	MDF 86235	0.137	Structure Sections	1.0000	---	0.13700	AAF	0.13700	All dampers same
D-3	Damper Operator	1	MPL 86440	0.00045	Electric Motors	0.3000	---	0.0039	M/H	0.00390	Cylinder (air) not an electric motor—emergency usage
FC-1D	Power Damper	1	MDF 86234	0.137	Structure Sections	1.0000	---	0.1370	AAF	0.13700	All dampers same
D-4	Damper Operator	1	MPL 86440	0.00045	Electric Motors	0.3000	---	0.00390	M/H	0.00390	Cylinder (air) not an electric motor
D3-6	Duct	1 Lot	MSS 87751	0.0001	Blower Duct	0.5125	---	0.10000	STL	0.10000	Estimate for duct
D3-4	Duct	1 Lot	MSS 87667	0.0001	Blower Duct	0.5125	---	0.10000	STL	0.10000	Estimate for duct
D5-3	Structure	1 Lot		0.0001	Structure Sections	1.0000	---	0.00100	STL	0.00100	Estimate for structures
HC-8D	Hand Damper	1	MDF 86201	0.0137	Structure Sections	1.0000	---	0.13700	STL	0.13700	All dampers same as power dampers
HC-12D	Hand Damper	1	MEB 85465	0.0137	Structure Sections	1.0000	---	0.13700	STL	0.13700	All dampers same as power dampers
HC-1	Heating Coil	1	MEG 85313	0.140	Heating Element	0.020	---	0.1400	AAF	0.14000	Letter from Weigand Co. Dec. 1960
TC-3V	Autotransformer (Variac)	1	MPA 85340	0.700 0.00043 0.00027	Variac (Autotransformer)	1.500	---	0.4300	AAF	0.43000	American Air Filter value
TC-3P	Pneumatic Operator	1			Pneumatic Operator (Boeing)	4.000	---	0.02620	M/H	0.02620	Cylinder (air) identical to D-1, D-2
HL-1	High Temperature Limit Switch	1	MPL 85334	0.000417	Switches	0.1400	---	0.19360	M/H	0.19360	---
TC-3	Control Thermostat	1	MPB 85316	0.0136	Thermostats	0.0600	---	0.35500	M/H	0.35500	---
PNV-3	Solenoid Air Valve	1	MPL 85231	0.00002	Solenoid Valves	11.0000	---	0.02500	M/H	0.02500	Derated for cycling only
C2	Magnetic Contactor	1	MEA 85326	0.000246	Contactors	0.2500	---	0.000246	Allen B	0.000246	Allen-Bradley data
CB-5	Circuit Breaker	1	MEB 85287	0.00183	Circuit Breakers	0.1375	---	0.00183	ITE	0.00183	ITE data—AAF derated
PE-5	P.E. Switch No. 5	1	MPL 85235	0.00005	Switches	0.1400	---	0.02400	M/H	0.02400	---
RE-5	Restrictor No. 5	1	MPL 85233	0.0000003	Restrictors	0.5900	---	0.0001	STL	0.00010	STL estimate
SW-5	Manual Switch	1	MEL 85590	0.00151	Toggle Switch	0.060	---	0.00151	AAF	0.00151	Allen-Bradley data
EIS-2	EIS Filter (1053A)	3	MEL 87209	0.198	Electric Filters	1.035	+0.288	0.4860	AAF	0.48600	Sprague data
D4-3	Electrical Connections	1 Lot		0.010	Cable Assemblies	0.0200	---	0.0010	STL	0.00100	Estimate for electrical connectors
EIS-1	EIS Filter (1053A)	1	MEL 87209	0.066	Electrical Filters	0.345	+0.096	0.1620	AAF	0.16200	Sprague data
FZ-3	Fuse	1	MS 90088-27	0.300	Fuses	0.5000	---	0.300	AAF	0.30000	Electro-Technical Magazine
OC-1C	Carbon Canister	1	MAD 85463	0.00224	Mechanical Filter	0.3000	---	0.00224	AAF	0.00224	American Air Filter estimate of vendor data
OC-1F	Fan	1	MAD 85462	0.0108	Exhaust Fans	0.2250	---	0.0108	AAF	0.01080	Clarage fan data
OC-1M	Fan Motor (1/50 hp)	1		4.29	Electrical Motors	0.3000	---	2.15000	STL-50%	2.15000	Derating of Reliance Electric data
SW-OC	Manual Starter	1	MAD 85161	0.016	Contactor	0.2500	---	0.0160	AAF	0.01600	Allen-Bradley data
EIS-3	EIS Filters (1051A)	1	MED 87207	0.066	Electrical Filters	0.3450	+0.139	0.2050	AAF	0.20500	Sprague data
EIS-4	EIS Filters (1051A)	1	MED 87207	0.066	Electrical Filters	0.3450	+0.139	0.2050	AAF	0.20500	Sprague data
SA-1	Sound Box and Register	1	MDB 86813	0.0147	Structure Section	1.0000	---	0.00100	STL	0.00100	Estimate for structure
C1	Magnetic Contactor (April only)	1	MEA 86629				+0.000246			0.000246	
RS-1	Resistor (April only)	3	MEL 87225				+0.819			0.819	
SW-HC	Disconnect (Nov. only)	1		0.00151	Switch	0.140	-0 00151	0.00151	AAF	---	Same as estimate for Allen-Bradley manual switch

SUBSYSTEM D: EMERGENCY WATER STORAGE

FACILITY: LCF(SRCC) NORMAL, LCF(LCC) NORMAL

AMERICAN AIR FILTER November - 61					HOLLADAY AND WESTCOTT November - 61			SPACE TECHNOLOGY LABORATORIES, INC.			
Symbol	Component Name	Quantity	AAF Part No.	AAF Fail Rate Per 10^6 Hr	Corresponding Component	H and W Fail Rate Per 10^6 Hr	AAF April—Fail Per 10^6 Hr	STL Nov—Fail Per 10^6 Hr	Source and K Factor	STL April—Fail Per 10^6 Hr	Comments
T-3	Emergency Water Storage	1 NIC		---							
HX-101	Heat Exchanger	1 NIC		---							
P-1	Circulating Pump (with seal)	1	MEA 85177	1.57	Pump	13.5000	---	6.767	AAF	6.76700	Derated like Worthington but 0.1 in place of 0.01
MT-P1	Pump Motor (1/4 hp) AC	1		4.29	Electric Motor	0.3000	---	2.5000	STL-50%	2.15000	Derating of Reliance Electric Co. data
SW-P1	Manual Starter	1	MEA 87334	0.0016	Contactor	0.2500	---	0.0016	AAF	0.00160	Allen-Bradley data
D1-9	Blast Valve 1-1/4" brine line	2 NIC		---							
D1-2	Flexible Pipe	2	MEA 86433	0.020	Hose	4.0000	---	0.40000	STL	0.40000	Estimate for flexible pipe
TA-3	Sweet Water Alarm Sensor and Bulb	1	MPL 85322	0.000417	Temperature Bulb	1.0000	---	0.09680	M/H	0.09680	AAF has revised these figures in TWO documents
TS-3	Target Air Gauge	1	MPA 85317	0.015	Pressure Gage	4.0000	---	0.01190	M/H	0.01190	
D1-12	Manual Water Valve	3	MRA 86100	0.0438	Shut-off Valve	19.5000	---	0.08730	STL	0.08730	Water Valve
D1-14	Check Valve	2	MRA 86101	0.020	Check Valve	10.0000	---	0.03000	STL	0.03000	Water check valve
D1-11	Drain Valve	1	MRA 86099	0.0146	Transfer Valve	0.5000	---	0.02910	STL	0.02910	Water Valve
D1-10	Pipe	1 Lot		0.001	Lines and Fittings	0.2000	---	0.10000	STL	0.10000	Estimate for pipe
D1-18	Shock Attenuator	1	MSS 87304	0.100	Vibration Mount	0.8750	---	0.11000	STL	0.11000	STL estimate (spring)
D1-12	Manual Valve	2 NIC		---							
D1-15	Water Line Strainer	1	MBA 86772	0.160	Mechanical Filter	0.3000	---	0.10000	STL	0.10000	Estimate for metal screens
D1-2	Flexible Pipe	2	MBA 87180	0.020	Hose	4.0000	---	0.40000	STL	0.40000	Estimate for flexible pipe
D1-1	Balancing Cock	1 (LCC)		0.040	Transfer Valve (LCC)	0.5000	---	0.04000	AAF	0.04000	STL Est. (ref AAF)
D1-1	Balancing Cock	2 (SRCC)		0.060	Transfer Valve (SRCC)	1.0000	---	0.06000	AAF	0.06000	STL Est. (ref AAF)
D1-16	Pipe	1		0.001	Line and Fitting	0.2000	-0.001	0.10000	STL		Estimate for pipe

SUBSYSTEM E: EXHAUST AIR SYSTEM

FACILITY: LCF(SRCC) NORMAL, LCF(LCC) NORMAL

AMERICAN AIR FILTER November - 61					HOLLADAY AND WESTCOTT November - 61			SPACE TECHNOLOGY LABORATORIES, INC.			
Symbol	Component Name	Quantity	AAF Part No.	AAF Fail Rate Per 10^6 Hr	Corresponding Component	H and W Fail Rate Per 10^6 Hr	AAF April—Fail Per 10^6 Hr	STL Nov—Fail Per 10^6 Hr	Source and K Factor	STL April—Fail Per 10^6 Hr	Comments
E-1	Exhaust Fan	1	MAC 86415	0.0108	Exhaust Fans	0.2250		0.0108	AAF	0.01080	Vendor data O.K.
E-1M	Fan Motor (1/4 hp)	1		4.29	Electric Motors	0.3000	---	2.1500	STL-50%	2.15000	Derating of Reliance Electric Co. data
SW-E1	Manual Starter	1	MEC 87765	0.00160	Contactors	0.2500	---	0.0016	AAF	0.00160	Allen-Bradley data
HC-9D	Hand Damper	1	MDF 86181	0.0137	Structure Sections	1.0000	---	0.13700	STL	0.13700	Same as power dampers
D3-5	Duct	1 Lot	MDH 87638	0.0001	Blower Ducts	0.5125	---	0.10000	STL	0.10000	Estimate for duct (STL)
D3-2	Flexible Duct	1	MAG 87597-8	0.010	Hoses	2.0000	+0.010	0.10000	STL	0.20000	Estimate flexible duct (STL)

SUBSYSTEM F: CONTROL AIR SUPPLY

FACILITY: LCF(SRCC) NORMAL, LCF(LCC) NORMAL, LF NORMAL

AMERICAN AIR FILTER November - 61					HOLLADAY AND WESTCOTT November - 61			SPACE TECHNOLOGY LABORATORIES, INC.			
Symbol	Component Name	Quantity	AAF Part No.	AAF Fail Rate Per 10^6 Hr	Corresponding Component	H and W Fail Rate Per 10^6 Hr	AAF April—Fail Per 10^6 Hr	STL Nov—Fail Per 10^6 Hr	Source and K Factor	STL April—Fail Per 10^6 Hr	Comments
AS-1	Air Compressor Includes Motor	1	MPK 85364	0 600	Compressors and Contractors (Boeing)	1 5000	---	2.0000	Estimate (Retrofit to 1.400)	2.0000	New motor (estimate 0.40) and new drive coupling, unload, = 0.73 same compressor = 0.258 Total = 1.40/for E.C.P.
PRV-1	Pressure Reducing Valve	1	MPK 85365		Electric Motors	0.3000					
SW-4	Manual Starter	1	MPL 87764	0.0016	Contactors	0.2500	---	0.0016	AAF	0.00160	Allen Bradley data
P1-1	Control Air Supply Piping	1 Lot		0.100	Lines and Fittings	0.2000	---	0.1000	STL	0 10000	Pipe estimate (STL)
C-1	3 Way Reversing Air Valve (SRCC only)	1	MPF 85314	0.000001	3 Way Valves	4.6000	+0.000001	0.0595	M/H	0 05950	---
C-2	Cumulator (SRCC only)	1	MPF 85234	0.0000003	Accumulators	7.2000	+0.0000003	0.0238	M/H	0.02380	---
PNV-4	Solenoid Air Valve (SRCC only)	1	MPL 85231	0.00002	Solenoid Valves	11.0000	+0.00002	0.0250	M/H	0.02500	Derated for cycling only
RE-6	Restrictor (SRCC only)	1	MPL 85233	0.0000003	Restrictors	0.5900	+0.0000003	0.0001	STL	0 00010	STL estimate
D1-3	Quick Disconnects	2	MRA 86400	0.0572	Flexible Couplings	1.3750	---	0 0572	AAF	0.05720	Snap-Tite data
D1-2	Flexible Pipe	1	MAK 87009	0.016	Hoses	2.0000	---	0.2000	STL	0.20000	STL estimate for flexible pipes
D1-1	Balancing Cock	1	MRL 86621	0.020	Transfer Valves	0.5000	---	0.0200	AAF	0.02000	AAF estimate of vendor data
D1-2	Flexible Pipe	1	MAK 86420	0.010	Hoses	2.0000	---	0.2000	STL	0.20000	STL estimate for flexible pipe

SUBSYSTEM G: EMERGENCY AIR HANDLING
FACILITY: LCF(LCC) EMERGENCY, LCF (SRCC) EMERGENCY

AMERICAN AIR FILTER November - 61					HOLLADAY AND WESTCOTT November - 61			SPACE TECHNOLOGY LABORATORIES, INC.			
Symbol	Component Name	Quantity	AAF Part No.	AAF Fail Rate Per 10^6 Hr	Corresponding Component	H and W Fail Rate Per 10^6 Hr	AAF April—Fail Per 10^6 Hr	STL Nov—Fail Per 10^6 Hr	Source and K Factor	STL April—Fail Per 10^6 Hr	Comments
FC-2D	Power Damper	1	MDF 86235	0.13700	Structure Section	1.0000	---	0.13700	AAF	0.13700	STL estimate all dampers
D-3	Damper Operator	1	MPL 86440	0.00045	Electric Motor	0.3000	---	0.00390	M/H	0.00390	Air cyl not electric motor
FC-1D	Power Damper	1	MDF 86234	0.13700	Structure Section	1.0000	---	0.13700	AAF	0.13700	STL estimate all dampers
D-4	Damper Operator	1	MPL 86440	0.00045	Electric Motor	0.3000	---	0.00390	M/H	0.00390	Air cyl not electric motor
CC-1	Cooling Coil	1	MBF 86787	0.01600	Lines and Fittings	0.2000	---	0.10000	STL	0.10000	Coil (H.X.) STL pipe estimate
S-1	Fan	1	MEA 85138	0.01080	Exhaust Fan	0.2250	---	0.01080	AAF	0.01080	Clarage fan data
S1-M	Fan Motor (DC)	1		8.22000	Electric Motor	0.3000	---	4.11000	STL-50%	4.11000	STL derates Joy-Westinghouse
PE-7	P.E. Switch No. 7	1	MPL 85236	0.00010	Switch	0.1400	---	0.02400	M/H	0.02400	---
SW-8	Manual Switch	1	MEL 85590	0.00151	Toggle Switch	0.0600	---	0.00151	AAF	0.00151	Allen-Bradley data
D4-5	Electrical Connections	1 Lot		0.01000	Cable Assembly	0.0200	---	0.00010	STL	0.00010	Estimate for electrical conduit
D3-6	Duct	1 Lot	MSS 87751	0.00010	Blower Duct	0.5125	---	0.10000	STL	0.10000	STL estimate for ducts
D5-5	Structure	1 Lot		0.00010	Structure Section	1.0000	---	0.00100	STL	0.00100	Estimate for structure (STL)
M-6	Motor Starter	1	MEA 85143	0.00047	Contactor	0.2500	---	0.00025	AAF	0.00025	Allen-Bradley data (switch + surge coil)
FZ-4	Fuse	1	MS 90088-23	0.30000	Fuses	0.5000	---	0.30000	AAF	0.30000	Electro-Tech Mag (British)

SUBSYSTEM H: EMERGENCY CHILLED WATER

FACILITY: LCF (SRCC) EMERGENCY, LCF(LCC) EMERGENCY

AMERICAN AIR FILTER November - 61					HOLLADAY AND WESTCOTT November - 61			SPACE TECHNOLOGY LABORATORIES, INC.			
Symbol	Component Name	Quantity	AAF Part No.	AAF Fail Rate Per 10^6 Hr	Corresponding Component	H and W Fail Rate Per 10^6 Hr	AAF April—Fail Per 10^6 Hr	STL Nov—Fail Per 10^6 Hr	Source and K Factor	STL April—Fail Per 10^6 Hr	Comments
P-2	Pump (with seals)	1	MEA 85176	1.57000	Pump	13.5000	---	6.76700	AAF	6.76700	STL derates Worthington x 10
MT-P2	Pump Motor (DC)	1		8.93800	Electric Motor	0.3000	---	4.47000	STL-50%	4.47000	STL derates Reliance Electric data
PE-6	P. E. Switch No. 6	1	MPL 85236	0.00010	Switch	0.1400	---	0.02400	M/H	0.02400	---
SW-P2	Manual Starter	1	MEA 85141	0.00160	Contactor	0.2500	---	0.00160	AAF	0.00160	Allen-Bradley data
D1-3	Quick Disconnect	2	MBL 85436	0.05720	Flexible Coupling	1.3750	---	0.05720	AAF	0.05720	Snap-Tite Records via AAF
CC-1	Cooling Coil	1	MBF 86787	0.01600	Lines and Fittings	0.2000	---	0.10000	STL	0.10000	STL estimate for Cooling Coil is = to piping
HX-101	Heat Exchanger	NIC		---							
T-3	Water Storage Tank	NIC		---							
D1-2	Flexible Pipe	2	MBA 86433	0.02000	Hoses	4.0000	---	0.40000	STL	0.40000	STL estimate for flexible pipe
D1-10	Pipe	1 Lot		0.00100	Lines and Fittings	0.2000	---	0.10000	STL	0.10000	STL estimate for pipe
D1-11	Drain Valve	1	MRA 86099	0.01460	Transfer Valve	0.5000	---	0.02920	STL	0.02920	STL derates AAF (x2)
D1-12	Manual Water Valve	3	MRA 86100	0.04380	Shutoff Valve	19.5000	---	0.08730	STL	0.08730	Water valve
D4-6	Electrical Connections	1 Lot		0.01000	Cable assembly	0.0200	---	0.00010	STL	0.00010	STL estimate for electrical conduit
D1-14	Check Valve	2	MRA 86101	0.02000	Check Valves	10.0000	---	0.03000	STL	0.03000	Water check valve
D1-18	Shock Attenuator	1	MSS 87304	0.10000	Vibration Mount	0.8750	---	0.11000	STL	0.11000	STL estimate for spring
D5-6	Structure	1 Lot		0.00010	Structure Section	1.0000	---	0.00100	STL	0.00100	STL estimate for structure
D1-2	Flexible Pipe	2	MBA 87180	0.02000	Hoses	4.0000	---	0.40000	STL	0.40000	STL estimate for flexible pipe

SUBSYSTEM J: EMERGENCY AIR PURIFICATION

FACILITY: LCF(SRCC) EMERGENCY, LCF(LCC) EMERGENCY

AMERICAN AIR FILTER November - 61					HOLLADAY AND WESTCOTT November - 61			SPACE TECHNOLOGY LABORATORIES, INC.			
Symbol	Component Name	Quantity	AAF Part No.	AAF Fail Rate Per 10^6 Hr	Corresponding Component	H and W Fail Rate Per 10^6 Hr	AAF April—Fail Per 10^6 Hr	STL Nov—Fail Per 10^6 Hr	Source and K Factor	STL April—Fail Per 10^6 Hr	Comments
KU-1F	Fan KO_2 Unit	1	---	0.0108	Exhaust Fan	0.2250	---	0.01080	AAF	0.01080	Clarage fan data
KU-1M	Fan Motor KO_2 Unit (DC)	1	MAE 85188	8.94	Electric Motor	0.3000	---	4.47000	STL-50%	4.47000	Reliance Electric Co. derated
KU-1C	Canister KO_2 Unit	1	---	0.00224	Mechanical Filter	0.3000	---	0.00224	AAF	0.00224	AAF data (change each 3 months.)
SW-9	Manual Starter	1	MEA 85148	0.0016	Contactors	0.2500	---	0.00160	AAF	0.00160	Allen-Bradley data
EB-5	EB Filter (1055A)	1	MEA 87211	0.06600	Electric Filters	0.3450	0.054	0.06600	AAF	0.01200	Sprague Electric Co. data
EB-6	EB Filter	1	---	0.06600	Electric Filters	0.3450	0.054	0.06600	AAF	0.01200	Sprague Electric Co. data
D5-4	Structure	1 Lot	---	0.0001	Structure Section	1.0000	---	0.00100	---	0.00100	STL estimate for structure
D4-4	Electrical Connections	1 Lot	---	0.010	Cable Assembly	0.0200	---	0.0010	---	0.00010	Estimate for electric conduits

SUBSYSTEM K: AIR HANDLING - LAUNCHER

FACILITY: LF NORMAL

AMERICAN AIR FILTER November - 61					HOLLADAY AND WESTCOTT November - 61			SPACE TECHNOLOGY LABORATORIES, INC.			
Symbol	Component Name	Quantity	AAF Part No.	AAF Fail Rate Per 10^6 Hr	Corresponding Component	H and W Fail Rate Per 10^6 Hr	AAF April—Fail Per 10^6 Hr	STL Nov—Fail Per 10^6 Hr	Source and K Factor	STL April—Fail Per 10^6 Hr	Comments
F-4	Filter	1	MAF 85264	0.00224	Mechanical Filter	0.3000	---	0.00224	AAF	0.00224	AAF own files
HC-10D	Hand Damper	1	MDF 86467	0.01370	Structure Sections	1.0000	---	0.13700	STL	0.13700	Same as power dampers
HC-7D	Hand Damper	1	MAF 85369	0.01370	Structure Sections	1.0000	---	0.13700	STL	0.13700	Same as power dampers
D3-3	Duct	1 Lot	MAF 87294	0.00010	Blower Ducts	0.5125	---	0.10000	STL	0.10000	All ducts 0.1 (STL)
HC-6D	Hand Damper	1	MAF 85967	0.01370	Structure Section	1.0000	---	0.13700	STL	0.13700	Same as power dampers
F-3	Filter	1	MAF 85264	0.00224	Mechanical Filter	0.3000	---	0.00224	AAF	0.00224	Estimate filters are to be changed every 3 months
TC-1D	Face and By-Pass Dampers	1	MAF 87086	0.13700	Structure Sections	1.0000	---	0.13700	AAF	0.13700	All dampers same
D-5	Damper Operator	1	MPL 86441	0.54000	Electrical Motors	0.3000	---	0.03930	M/H	0.03930	Cylinder (air) not an electric motor
TC-1	Control Thermostat	1	MPL 85321	0.10000	Thermostat	0.0600	---	0.38270	M/H	0.38270	M/H data looks good
PNV-1	Solenoid Air Valve	1	MPL 85231	0.00002	Solenoid Valves	11.0000	---	0.02500	M/H	0.02500	Derated for cycling only
CC-1	Cooling Coil	1	MBL 86640	0.01600	Lines and Fittings	0.2000	---	0.10000	STL	0.10000	STL estimate for cooling coil (piping)
D1-3	Quick Disconnect	2	MBF 85436	0.05720	Flexible Couplings	1.3750	---	0.05720	AAF	0.05720	Snap-Tite records
D1-2	Flexible Pipe	2	MBF 87011	0.02000	Hoses	4.0000	---	0.40000	STL	0.40000	All flexible pipe 0.2 (STL)
D1-6,	Brine Piping	1 Lot	CU TYPE K	0.00100	Lines and Fittings	0.2000	---	0.10000	STL	0.10000	All pipe 0.1 (STL)
D1-9	Blast Device 1-1/4 Brine blast valve	2 NIC		---							
D1-12	Manual Valve (Gate Valves)	2 NIC		---							
T-1	Expansion Tank	1	MBG 85227	0.00100	Tanks	0.1500	---	0.00100	STL	0.00100	Estimate for structures
D1-13	Safety Valve	1	MBG 85228	0.05000	Vent and Relief Valve	5.7000	---	0.05000	AAF	0.05000	H and W data very unrealistic
S-4	Fan	1	MEF 87269	0.01080	Exhaust Fans	0.2250	---	0.01080	AAF	0.01080	Clarage fan data
MT-1	Fan Motor (3 hp)	1		3.96000	Electric Motors	0.3000	---	1.98000	STL-50%	1.98000	Derating of Reliance Electric data
HC-11D	Hand Damper	1	MAF 85533	0.06450	Structural Sections	1.0000	---	0.13700	STL	0.13700	Same as power dampers
M-1	Motor Starter	1	MEL 85155	0.00025	Contactors	0.2500	---	0.00025	AAF	0.00025	Allen Bradley data (switch and surge coil)
CB-4	Circuit Breaker	1	MEF 85285	0.00183	Circuit Breakers	0.1375	---	0.00183	AAF	0.00183	AAF derates ITE
PE-4	P. E. Switch No. 4	1	MPL 85235	0.00010	Switches	0.1400	---	0.02400	M/H	0.02400	AAF shows this to be 0.00005 in other records
EIS-8	EIS Filters (1052A)	3	MEF 87208	0.19800	Electrical Filters	1.0350	+0.286	0.19800	STL	0.48600	Sprague data
EIS-7	EIS Filters (1052A)	1	MEF 87208	0.06600	Electrical Filters	0.3450	+0.096	0.06600	STL	0.16200	Sprague data
D4-2	Electrical Connections	1 Lot		0.01000	Cable Assemblies	0.0200	---	0.00010	STL	0.00010	Estimate for electrical conduit
FZ-1	Fuse	1	MS 90088-23	0.30000	Fuses	0.5000	---	0.30000	AAF	0.30000	Electro-technical data
HC-13D	Manual Damper	1	MAF 85980	0.01370	-	---	+0.0137	---	---	0.13700	Manual and power dampers same
---	8" Air Blast Valve	1 NIC									
D5-2	Structure	1 Lot		0.00010	Structure Sections	1.0000	---	0.00100	STL	0.00100	STL structure estimate
D3-2	Flexible Duct	1	MAF 87290	0.01000	Hoses	2.0000	---	0.20000	STL	0.20000	STL duct estimate 0.2
HC-9D	Pressure Reducing Damper	1	MDF 86367	0.01370	Structure Sections	1.0000	---	0.13700	STL	0.13700	Same as power damper
FC-3D	Power Damper	1	MDF 86224	0.13700	Structure Sections	1.0000	---	0.13700	AAF	0.13700	All dampers same
D-4	Damper Operator (Nov. only)	1	MPL 86440	0.00045	Electric Motors	0.3000	---	0.00390	---	---	Not in system

SUBSYSTEM K: AIR HANDLING - LAUNCHER

FACILITY: LF NORMAL (Continued)

AMERICAN AIR FILTER November - 61					HOLLADAY AND WESTCOTT November - 61			SPACE TECHNOLOGY LABORATORIES, INC.			
Symbol	Component Name	Quantity	AAF Part No.	AAF Fail Rate Per 10^6 Hr	Corresponding Component	H and W Fail Rate Per 10^6 Hr	AAF April—Fail Per 10^6 Hr	STL Nov—Fail Per 10^6 Hr	Source and K Factor	STL April—Fail Per 10^6 Hr	Comments
FC-4D	Power Damper	1	MDF 86230	0.13700	Structure Sections	1.0000	---	0.13700	AAF	0.13700	All dampers same
D-3	Damper Operator	1	MPL 86440	0.00045	Electric Motors	0.3000	---	0.00390	M/H	0.00390	Air cylinder - not electric motor
TA-1	Thermostat	1	MPL 85320	0.00042	Thermostats	0.0600	---	0.09680	M/H	0.09680	---
PE-9	P.E. Switch No. 9	1	MPL 85235	0.00010	Switches	0.1400	---	0.02400	M/H	0.02400	---
EB-13	EB Filter (1050A)	1	MEF 87206	0.06600	Electric Filters	0.3450	+0.064	0.06600	AAF	0.13000	Sprague data
EB-16	EB Filter (1050A)	1	MEF 87206	0.06600	Electric Filters	0.3450	+0.064	0.06600	AAF	0.13000	Sprague data
TA-2	Thermostat	1	MPF 85327	0.00042	Thermostats	0.0600	---	0.09680	M/H	0.09680	---
PE-8	P.E. Switch No. 8	1	MPL 85236	0.00010	Switches	0.1400	---	0.02400	M/H	0.02400	---
PE-7	P.E. Switch No. 7	1	MPL 85235	0.00010	Switches	0.1400	---	0.02400	M/H	0.02400	---
EB-14	EB Filter (1050A)	1	MEF 87206	0.06600	Electric Filters	0.3450	+0.064	0.06600	AAF	0.13000	Sprague data
FA-1	Flow Controller	1	MPL 85315	0.00055	Flow and Press Regulator	2.1400	---	0.00750	M/H	0.00750	Not a pressure regulator
PE-6	P.E. Switch No. 6	1	MPL 85235	0.00010	Switches	0.1400	---	0.02400	M/H	0.02400	---
EB-17	EB Filter (1050A)	1	MEF 87206	0.06600	Electric Filters	0.3450	+0.064	0.06600	AAF	0.13000	Sprague data
D1-8	Drain Valve	1		0.01460	Transfer Valve	0.5000	-0.0146	0.02920	STL	---	Drain valve is shipping plug

SUBSYSTEM L LAUNCH TUBE HEATER SYSTEM
FACILITY· LF NORMAL

AMERICAN AIR FILTER November-61					HOLLADAY AND WESTCOTT November - 61			SPACE TECHNOLOGY LABORATORIES, INC			
Symbol	Component	Quantity	AAF Part No.	AAF Fail Rate Per 10^6 Hr	Corresponding Component	H and W Fail Rate Per 10^6 Hr	AAF April-Fail Per 10^6 Hr	STL Nov-Fail Per 10^6 Hr	Source and K Factor	STL April-Fail Per 10^6 Hr	Comments
FC-4D	Power Damper	1	MDF 86230	0.13700	Structure Section	1.0000	---	0.13700	AAF	0.13700	All dampers same cylinder (air) not an electric motor
D-3	Damper Operator	1	MPL 86440	0.00045	Electric Motor	0.3000	---	0.00390	M/H	0.00390	
FC-6D	Power Damper	1	MAJ 86583	0.13700	Structure Section	1.0000	---	0.13700	AAF	0.13700	All dampers same cylinder (air) not an electric motor
D-6	Damper Operator	1	MPL 86440	0.00045	Electric Motor	0.3000	---	0.00390	M/H	0.00390	
D3-4	Duct	1 Lot	MAF 87291	0.00010	Blower Duct	0.5125	---	0.10000	STL	0.10000	All duct 0.1 (STL)
D3-2	Flexible Duct	1	MAF 87293	0.01000	Hose	2.0000	---	0.20000	STL	0.20000	All flexible duct 0.2
S-3F	Launch Tube Fan	1	MEJ 86452	0.01080	Exhaust Fan	0.2250	---	0.01080	AAF	0.01080	Clarage fan data
S-3M	Fan Motor (1/3 hp))	1		4.29000	Electric Motor	0.30000	---	2.15000	STL-50%	2.15000	Derating of Reliance Electric data.
SW-S3	Manual Starter	1	MEJ 85163	0.00160	Contactors	0.25000	---	0.00160	AAF	0.00160	Allen-Bradley data
HC-2	Electric Heating Coil	1	MEJ 85137	0.14000	Heating Elements	0.0200	---	0.14000	AAF	0.14000	Letter from Weigand Company to AAF
TC-4V	Autotransformer (Variac)	1	MEJ 85341	0.70000	Variac (Boeing)	1.5000	---	0.43000	M/H	0.43000	AAF value
TC-4P	Pneumatic Operator	1		0.00070	Pneumatic Operator (Boeing)	4.0000	---	0.02620	M/H	0.02620	Cylinder (air) identical to D-1, D-2.
HL-1	High Temperature Limit Switch	1	MPL 85322	0.000427	Switches	0.1400	---	0.00042	AAF	0.00042	Johnson control data.
TC-4	Control Thermostat	1	MPL 85320	0.03340	Thermostats	0.0600	---	0.38720	M/H	0.38720	---
PNV-4	Solenoid Air Valve	1	MPL 85231	0.00002	Solenoid Valve	11.0000	---	0.02500	M/H	0.02500	Derated for cycling only
R-1	Control Relay Two Contacts	1	MEL 85165	0.00023	G. P. Relay	0.5000	---	0.00023	AAF	0.00023	
TC-5	Control Thermostat	1	MPJ 85328	0.10000	Thermostats	0.0600	---	0.19360	M/H	0.19360	---
C-3	Duplex Pressure Selector	1	MPJ 85323	0.00000	Selector Valve	16.0000	---	0.11380	M/H	0.11380	AAF value disregarded extremely small
CB-5	Circuit Breaker	1	MEJ 85286	0.00183	Circuit Breaker	0.1375	---	0.00183	ITE	0.00183	ITE data-AAF derated
EIS-9	EIS Filter (1053A)	3	MEL 87209	0.19800	Electric Filters	1.0350	+0.288	0.19800	AAF	0.48600	Sprague data
TA-4	Thermostat	1	MPL 85320	0.00042	Thermostat	0.0000	---	0.09680	M/H	0.09680	---
PE-10	P.E. Switch No. 10	1	MPL 85235	0.00010	Switches	0.1400	---	0.02400	M/H	0.02400	---
PE-11	P.E. Switch No. 11	1	MPL 85236	0.00010	Switches	0.1400	---	0.02400	M/H	0.02400	
FA-2	Flow Controller	1	MPL 85315	0.00055	Flow and Pressure Regulator	2.1400	---	0.00750	M/H	0.00750	Not a pressure Regulator
PE-12	P.E. Switch No. 12	1	MPL 85235	0.00010	Switches	0.1400	---	0.02400	M/H	0.02400	
EIS-15	EIS Filter (1050A)	1	MEF 87206	0.06600	Electric Filters	0.3450	+0.064	0.06600	AAF	0.13000	Sprague data
EIS-18	EIS Filter (1050A)	1	MEF 87206	0.06600	Electric Filters	0.3450	+0.064	0.06600	AAF	0.013000	STL estimate
D4-3	Electrical Connections	1 Lot		0.01000	Cable Assemblies	0.020	---	0.00010	STL	0.00010	Sprague data
FS-3	Fuse	1		0.30000	Fuses	0.5000	-0.3000	0.30000	AAF	---	Removed from April report by STL direction

SUBSYSTEM M: EMERGENCY AIR-LAUNCHER
FACILITY - LF EMERGENCY

AMERICAN AIR FILTER November - 61					HOLLADAY AND WESTCOTT November - 61			SPACE TECHNOLOGY LABORATORIES, INC.			
Symbol	Component Name	Quantity	AAF Part No.	AAF Fail Rate Per 10^6 Hr	Corresponding Component	H and W Fail Rate Per 10^6 Hr	AAF April — Fail Per 10^6 Hr	STL Nov — Fail Per 10^6 Hr	Source and K Factor	STL April — Fail Per 10^6 Hr	Comments
FC-3D	Power Damper	1	MDF 86224	0.13700	Structure Section	1.0000	---	0.13700	AAF	0.13700	STL estimate all dampers
D-4	Damper Operator	1	MPL 86440	0.00045	Electric Motor	0.3000	---	0.00390	M/H	0.00390	Air cyl. - <u>not</u> electric motor.
FC-4D	Power Damper	1	MDF 86230	0.13700	Structure Section	1.0000	---	0.13700	AAF	0.13700	STL estimate all dampers
D-3	Damper Operator	1	MPL 86440	0.00045	Electric Motor	0.3000	---	0.00390	M/H	0.00390	Air cyl. - <u>not</u> electric motor
FC-6D	Power Damper	1	MAJ 86583	0.13700	Structure Section	1.0000	---	0.13700	AAF	0.13700	STL estimate all dampers
D-6	Damper Operator	1	MPL 86440	0.00045	Electric Motor	0.3000	---	0.00390	M/H	0.00390	Air Cyl. - <u>not</u> electrical motor
S-2F	Emergency Fan	1	MEH 85139	0.01080	Exhaust Fan	0.2250	---	0.01080	AAF	0.01080	Clarage fan data.
S-2M	Fan Motor (DC)	1	---	8.22000	Electric Motor	0.3000	---	4.11000	AAF	4.11000	AAF derates Westinghouse.
PE-5	P. E. Switch No. 5	1	MPL 85236	0.00005	Switch	0.1400	---	0.02400	M/H	0.02400	---
SW-1	Manual Switch	1	MEL 85590	0.00151	Toggle Switch	0.0600	---	0.00151	AAF	0.00151	Allen-Bradley data
M-5	Motor Starter	1	MEH 85152	0.00047	Contactor	0.2500	---	0.00047	AAF	0.00047	Allen-Bradley data
ES-12	ES Filter (1054A)	1	MEH 87210	---	Electric Filters	0.3450	0.06126	0.06600	AAF	0.00948	Sprague data
ES-11	ES Filter	1	---	0.13200	Electric Filters	0.3450	0.06126	0.06600	AAF	0.00948	Sprague data
D4-4	Electrical Connections	1 Lot	---	0.01000	Cable Assemblies	0.0200	---	0.00100	STL	0.00100	STL estimate for electric conduit
D3-5	Duct	1 Lot	MAF 87292	0.00010	Blower Duct	0.5125	---	0.01000	---	0.10000	STL estimate for ducts
---	Electronic Equipment	NIC	---	---	---	---	---	---	---	---	---
FZ-4	Fuse (April only)	1	MS 90080-23	---	---	---	---	---	---	0.30000	Electro-Tech Mag Data (AAF)

EXHIBIT I

Subsystem Failure Rate Summary

Exhibit II is a tabulation of the comparative MTBF of major subsystems by failure data summation. The major subsystems are subdivided into their respective minor subsystems according to the plan presented in References 1 and 2. The various components making up each of the minor subsystems are tabulated with their failure rates in Exhibit I; Exhibit II then serves as a presentation of resultant MTBF.

Wing I Minuteman MTBF requirements are 14,000 hours for each of the major subsystems. It will be noted that the November AAF summary shows an LCF(SRCC) normal predicted MTBF of slightly less (13,440 hours) than the requirement, while both the LCF(LCC) normal and the LF normal far exceed the requirement with 21,725 and 27,600 hours respectively. These values decreased slightly at the time of issuance of the April report by AAF, the reason given being that Electro-Interference Suppression (E.I.S.) filter failure rates had been updated and increased from the preliminary November estimates. With the exception of the LCF(SRCC) normal major subsystem, however, the MTBF requirements were apparently still exceeded.

The MTBF reported by Holladay and Westcott in Reference 2, are less optimistic, as noted earlier. In fact, without the advance explanation in this report, it would appear that a very serious situation existed due to the 2,000- and 3,000-hour MTBF predictions by Holladay and Westcott. Contractually, the reliability design goal was stated as"...scheduled maintenance only once each 3 years, with the exception of air filters ....once every 3 months." The geographical dispersion of the launch sites precludes frequent maintenance, and the logistics requirements to meet 3000 hours MTBF for these systems would be quite extreme. Fortunately, for reasons previously indicated, the Holladay and Westcott estimates do not appear to be as close to a valid prediction as the AAF estimates.

STL evaluated the system component failure data, and through reestimation, selective use of manufacturer's data, and application of derating factors arrived at the failure rates tabulated in Exhibit I and summarized here. The STL-November column is a summary of STL-predicted failure

data utilizing the systems and components of Reference 1. The STL-April column is a reflection of equipment and failure data upgrading from November. It will be noted that the same minor subsystems are included in all the column tabulations up through the STL-April column. This is for comparative purposes only, showing the results of failure rate estimate differences on the same equipment. The final STL column is modified from the previous STL column by deletion of the emergency water storage minor subsystem and by application of the reporting efficiency factor, both mentioned earlier in this report.

The results in terms of predicted MTBF for all the Exhibit II tabulations are obvious. The LCF(SRCC) major subsystem is below the required 14, 000 hours. The other major subsystems exceed this requirement and, in fact, approximate the higher MTBF hours required of Wing II subsystems.

	SYSTEM AND SUBSYSTEM	Quantity	AAF Nov—Fail/10^6	H & W Nov—Fail/10^6	STL Nov—Fail/10^6	AAF April—Fail/10^6	STL April—Fail/10^6	STL Final Est. Reporting Eff. 0.80
NORMAL SYSTEMS	LCF (SRCC) NORMAL							
	A. Air Handling - Support Bldg.	2	10.68322	73.1175	9.76131	10.7	9.53913	
	B. Packaged Brine Chiller	2	46.05230	304.6073	51.32890	50.7	51.75686	
	C. Air Handling	1	6.21000	31.3275	5.69481	7.69	6.51479	
	D. Normal Oper. Emer. H_2O Stor.	1	6.33742	59.6250	10.46370	6.26	10.36370	
	E. Exhaust Air System	1	4.32620	4.2875	2.49940	4.34	2.59940	
	F. Control Air Supply	1	0.79882	31.5150	2.68720	0.799	2.68720	
			74.40796	504.4798	82.43532	80.50	83.46108	84.0199
			MTBF = 13,440	MTBF = 1,982	MTBF = 12,131	MTBF = 12,422	MTBF = 11,982	MTBF = 11,902
	LCF (LCC) NORMAL							
	A. Air Handling - Support Bldg.	1	5.38976	42.1200	5.15470	5.38	4.62840	
	B. Packaged Brine Chiller	1	23.04865	155.1262	24.08126	25.30	25.93130	
	C. Air Handling	1	6.21000	31.3275	5.69481	7.69	6.51479	
	D. Emer. Water Storage	1	6.29742	59.1250	10.42370	6.26	10.32370	
	E. Exhaust Air System	1	4.32620	4.2875	2.49940	4.34	2.59940	
	F. Control Air Supply	1	0.79882	8.1250	2.57880	0.799	2.57880	
			46.07085	300.1112	50.43267	49.80	52.75639	48.7732
			MTBF = 21,725	MTBF = 3,332	MTBF = 19,828	MTBF = 20,080	MTBF = 18,955	MTBF = 20,503
	LF NORMAL							
	B. Packaged Brine Chiller	1	23.06865	155.1172	24.10126	25.30	25.95130	
	F. Control Air Supply	1	0.79880	8.1250	2.57880	0.799	2.57880	
	K. Air Handling - Launcher	1	6.17217	43.3500	5.73576	6.80	6.18256	
	L. Launch Tube Heater System	1	6.20457	44.1700	4.86888	6.32	4.80858	
			36.24419	250.7622	37.28470	39.20	39.52124	45.4267
			MTBF = 27,600	MTBF = 3,988	MTBF = 26,821	MTBF = 25,510	MTBF = 25,303	MTBF = 22,013
EMERGENCY SYSTEMS	LCF (SRCC) EMERGENCY							
	G. Emergency Air Handling	1	8.83398	5.8075	4.92946	8.83	4.92946	
	H. Emergency Chilled Water	1	10.81240	55.8600	12.57740	10.80	12.70780	
	J. Emergency Air Purification	1	9.09674	2.7850	4.61774	8.98	4.50974	
			28.74312	64.4525	22.12460	28.60	22.14700	25.45630
			MTBF = 34,800	MTBF = 15,515	MTBF = 45,198	MTBF = 34,965	MTBF = 45,153	MTBF = 39,283
	LCF (LCC) EMERGENCY							
	G. Emergency Air Handling	1	8.83398	5.8075	4.92946	8.83	4.92946	
	H. Emergency Chilled Water	1	10.81240	55.8600	12.57740	10.8	12.70780	
	J Emergency Air Purification	1	9.09674	2.7850	4.61774	8.98	4.50974	
			28.74312	64.4525	22.12460	28.60	22.14700	25.45630
			MTBF = 34,800	MTBF = 15,515	MTBF = 45,198	MTBF = 34,965	MTBF = 45,153	MTBF = 39,283
	LF EMERGENCY							
	M. Emergency Air- Launcher	1	8.78728	6.0975	4.80248	8.96	4.98944	
			8.78728	6.0975	4.80248	8.96	4.98944	6.74701
			MTBF = 113,800	MTBF = 164,000	MTBF = 208,226	MTBF = 111,607	MTBF = 200,423	MTBF = 148,213

EXHIBIT II

Reporting Efficiency Factor

It was noted that no use has been made of a reporting efficiency factor in any of the reviewed reports. This is the term applied when not all failures of equipment in operation or under test are reported, resulting in overoptimistic failure rate tabulations. Failure to report such failures can be due to a number of reasons, including the seemingly relative unimportance of reporting minor malfunctions, contrast in time between the writing of a failure report and accomplishing minor adjustment or small part exchange, lack of knowledge of importance of failure reporting, lost or misplaced records, possible lack of time, etc. Frequently a reporting agency is unable to pinpoint a "pertinent" failure among many minor adjustments required, ordinary inept installation-caused malfunctions, storage or transport hazards, etc. The fact remains that, consistently, all failures are not reported. Careful review of the naval aircraft failure reporting system a few years ago revealed, for example, that only slightly over one-half of all component (major or minor) failures were actually reported from the field. Recognizing that the condition led to highly optimistic failure predictions and severely hampered accurate logistics planning, among other things, a careful review of reporting sources was made. Thorough indoctrination of all responsible reporting personnel plus application of significant pressure at higher levels resulted in increase of the failure reporting efficiency to approximately 85 percent. The Minuteman predominately "commercial" type of environmental control system has a reporting efficiency factor almost impossible to calculate due in most part to the multitude of required reporting sources. But it must certainly be 80 percent or less. In order to maintain a comparative failure rate analysis, STL in its preliminary tabulations of Exhibits I and II assumed a 100 percent reporting efficiency. The final column of Exhibit II applies the 80 percent reporting efficiency factor to component failure data utilized in the total subsystems failure summations. Recognizing that this factor is an approximation, STL nonetheless submits the resulting figures of the final column of Exhibit II as the best available prediction of MTBF for the major subsystems.

MTBF—Demonstration Requirement

It has been indicated in Reference 1, affirmed by Reference 2, and reaffirmed by STL evaluation that the basic MTBF requirement of 14, 000 hours for the LCF(SRCC) normal subsystem has not been met, at least by calculation. The predicted MTBF for this particular subsystem was tabulated in Exhibit II, and in all cases calculation was based upon series treatment of individual component and subsystem failure rates. Since the reliability requirement was stated in terms of MTBF hours, the approach is acceptable. But determination of the real MTBF of a system by demonstration may be quite different from the value determined analytically. For this reason a sequential demonstration plan was set up by AAF based upon the MTBF requirement of 14, 000 hours.

The sequential sampling plan devised by AAF utilizes a practical reliability-monitoring plan to accumulate the time required to demonstrate the requirement. It is proposed that actual system operation time at the test installation base (Vandenberg Air Force Base) and at the Wing I (Malmstrom Air Force Base) installation site be utilized for demonstration time. The sequential sampling plan proposed is intended to give a running capability to decide whether or not the number of failures versus operation time is continuing at an acceptable rate. MTBF determination as such will not specifically result from the plan, but a point estimate of the existing MTBF is obtainable at any time simply by dividing the total accumulated time by total number of observed failures.

An examination of the MTBF requirement, however, reveals that complete definition of the requirement is lacking. A complete requirement should include some measure of confidence and should include a sampling plan to statistically refer test, demonstration, or operational use results back to the requirement. The requirement of simply 14, 000 hours MTBF allows a number of interpretations. Three such interpretations are

1) As the design objective
2) As the lower 90-percent confidence limit on the operational characteristic (OC) curve.
3) As the upper 95-percent confidence limit on an OC curve.

In each of the above three cases, the implication of the MTBF desired would be different. In interpretation 1, the true MTBF being aimed for is 14, 000 hours. This requires that a statistical sampling demonstration program be developed which provides the consumer high protection against accepting equipment whose estimated MTBF is not much less than 14, 000 hours; e.g., that there is a 90-percent assurance that the true MTBF is greater than 13, 500. Interpretation 2 implies that the true, or design, objective MTBF is considerably more than 14, 000 hours (perhaps 20, 000 to 25, 000 hours) for successful statistical demonstration. Interpretation 3 (and this is the interpretation given by the AAF Reliability Demonstration Program Plan) states that if 14, 000 hours MTBF is the true MTBF, then there is 95-percent probability of the equipment passing the statistical sampling requirement. However, with the AAF demonstration plan there is also a 50-percent chance of the equipment successfully passing the requirements with a MTBF as low as 7000 to 8000 hours. There is also a 10-percent probability of the equipment passing the demonstration plan with a MTBF as low as 2800 hours. Thus, as seen from this discussion, the implications regarding the true MTBF of the equipment can very likely range all the way from less than one-half the 14, 000 hours to more than twice the 14, 000 hours. The importance of the incompletely defined MTBF requirement noted above, together with the possible results of the sampling demonstration plan, was not appreciated when it was originally stated. However, subsequent and much better requirements, which completely define the acceptable minimums, are contained in the Work Statement for Wings III and IV. In these plans it is stated that the minimum MTBF requirement shall be interpreted as the 50-percent point on the OC curve of the sequential sampling plan. The contractor is required to submit the OC curve of the sampling plan and the charts for plotting failures versus time data, which shall include rejection and acceptance lines corresponding to α and β equal to 10-percent. This type of requirement describes the sampling plan limits and defines the results expected so that the customer will have no question as to what he is buying; this protects him from accepting systems with appreciably less than the desired reliability.

IV. RECOMMENDATIONS

The documents which are the subject of review of this report are dated November 1961 and April and May of 1962. It is apparent that recommendations to provide overall corrections for design upgrading of Wing I components and/or subsystems are not relevant at this late date, especially since usual techniques of redundundancy application or overdesign were not permitted in Wing I.

The basic requirement of 14, 000 hours MTBF for each of the major subsystems does not appear extreme, as will be noted in the summary; depending upon interpretation of the requirements, all subsystems may meet MTBF demonstration requirements. But by probabilistic assessment, the LCF(SRCC) normal system, at least, does not meet the requirement. Ordinarily, techniques of reliability such as component elimination or reduction, application of redundancy methods, or component or system upgrading and improvement would be employed. For reliability upgrading of this Wing, the Contractor has been told that with the exception of the air compressor, stricter quality control and improved installation methods were the only avenues open to them.

The one component currently undergoing change and intended to be retrofitted into Wing I is the air compressor. The belt drive of the current air compressor will be replaced with a flexible shaft, and the failure rate prediction is $1.40/10^6$ hours versus the $2.00/10^6$ now estimated. This change alone will boost the SRCC MTBF to well over 12, 000 hours.

Electric motors are among the components with high failure rate which should be examined for possible reliability improvement. The important improvement required would be in upgrading of bearings, since bearing failure is a prime failure mode. If failure rate of the fan and pump motors alone could be reduced to the generic mean rate ($0.300/10^6$ hours) the LCF(SRCC) MTBF prediction would increase to 13, 600 hours. This is the subject of study at the present time for inclusion in future Wings. Many other avenues of investigation for increasing subsystem and component MTBF are currently being investigated for future Wing requirements. Alternate

components have been suggested in many areas. New design models of brine chiller and air conditioner with resulting system changes being developed under separate R and D contract by AAF are expected to result in more than double the current SRCC MTBF hours predicted.

The recommendations offered by STL at this time include:

A. <u>For Wing I</u>:

1) Accept the currently predicted STL MTBF for Wing I as the best possible, utilizing currently available failure data and prediction techniques.

2) Closely monitor all failure data which will be initiated by the Installation Contractor and Air Force.

3) Assure that corrective action is initiated on a priority basis where required.

4) Maintain close liaison and coordination with Installation and Quality Control personnel and checkout procedures.

5) If necessary, because of severe decrease in MTBF, recommend for retrofit into Wing I any applicable change currently being investigated.

B. <u>For Future Wings</u>:

1) Completely define the reliability requirements as to MTBF, including confidence factors and/or a sampling plan to statistically refer test, demonstration, or operational use results back to the requirement.

2) Require compliance with existing military documents (for example, MIL-R-27542), requesting submittal of maintenance analyses, safety margin calculations, failure reporting system plan, feasibility studies, apportionment, vendor selection and control program, reports submission, and other normal reliability program constituents.

3) Define all reliability terms used in reports.

4) Require complete environmental description for all systems as well as normal operating periods and survival periods as part of the reliability report.

5) Allow contractor scheduled time and freedom to prepare detailed component failure analyses by submitting requests for proposal 6 months ahead of time.

6) Require complete component description, and discourage use of terms such as "lot," "run," and "group," for failure rate assignments.

7) Require estimation of reporting efficiency factor for individual subvendors and include this in calculations.

Many of the foregoing comments could be classed as techniques or methods and perhaps need not appear in written reliability requirements. But they need to be covered whether written or required verbally. Such a thorough reliability background enables possible problem areas to be easily discerned, corrective action to be more easily applied, and the importance of individual system components to be easily defined.

The importance of reliability design freedom cannot be overestimated. Little more system MTBF can be gained without employing the methods of overdesign, use of redundancy, etc., covered previously.

V. SUMMARY

In the areas of failure rate determination and failure data collection, American Air Filter Company has shown good effort in Reference 1 and subsequent reports. Existing industry problems with equipment failure reporting methods and requirements and limited operation information on new equipments preclude availability of good quality failure data. Data estimates, compared with STL estimates, are optimistic but not generally extreme. The failure and safety analyses submitted by Reference 1 are informative and acceptable, and the block diagrams are generally well done. The reliability analysis structure utilizing a serial arrangement concept for all components and subsystems is proper with two exceptions, the emergency water storage system and the incorporation of the alarm component failure rates into the system estimates.

Lack of system redundancy, limited upgrading recommendations, the time limitations for gathering environmental system component information, and minimum overdesign evident in the reports were generally caused by limitations imposed by STL, The Parsons Company, or the Air Force. For example, the Wing I Real Property Installed Equipment concept does not permit use of design redundancy. Other restrictions to a complete reliability program are discussed in Reference 4 for Wing I environmental control systems equipment only.

The Reference 2 report in the reliability area provides little applicable constructive criticism for Wing I. Many good suggestions for upgrading systems apparently would have been implemented by AAF if they had been given the freedom or the authority to do so. Obviously, for example, redundancy may have been considered for those components with extremely high failure rates had contrary system design limitations not been imposed. Occasionally the part failure information used by AAF was not of good quality and was not well applied; however, the approach of Reference 2 was much less satisfactory in these respects. The failure rates used in this latter reference were very general, part-type generic mean values and, it is suspected, reflect more missile use than commercial,

or missile ground support systems use. Derating or application factors were not employed in Reference 2 for various reasons. In fact, it is difficult to classify MTBF determination of Reference 2 as much more than a very rough first estimate.

The specification requirement contained in the Statement of Work calls for a minimum of 14, 000 hours MTBF for each of the three major subsystems. Disregarding the fact that the same MTBF is required for three subsystems of different complexities, so that in all probability the estimated MTBF's will probably not be identical, this report shows that one of the three subsystems, the LCF(SRCC) Normal, does not meet the requirement. The final STL column of Exhibit II shows estimated MTBF of 11, 902 hours for LCF(SRCC) Normal, 20, 503 hours for LCF(LCC) Normal, and 22, 013 hours for LC Normal. No claim of compliance with the requirement of 14, 000 hours per se is made by Reference 1 for the LCF(SRCC) Normal. It is expected that employment of recommendations for upgrading system components along with current and proposed ECP's would raise the MTBF to an acceptable level, but change effectivity will probably not be reflected back into Wing I to any great degree.

It should be realized that a <u>precise</u> prediction of MTBF is not possible, because of various factors which cannot be evaluated at this time. For example, the effect on component reliability of storage methods employed is one such factor. The effect of methods used to transport and handle equipment is unknown. Since the assembled equipment is transferred to an Installation Contractor who subsequently adds racks, panels, etc., before turning the site over to the Air Force, a reliability degradation can be expected in this area. Additional problems may arise from the revamping of the silo entrance in Project "Button Up." There is good probability that cement dust and other contamination will not be completely eliminated before Air Force acquisition of the facility. This, of course, may result in an initially high number of failure reports. Comparison of predicted MTBF values at this time with the actual MTBF hours resulting from extended field operation at some later date will be made.

It appears obvious that the stringent limitations of system design imposed upon this Wing due to costs, scheduling, or other reasons must be lifted on future wings if the increased MTBF requirements are to be met. Very little actual reliability increase can be expected solely from methods of better quality control or installation processes. These are, in fact, only comparative processes. In the future, Wing Associate Contractors must be permitted greater freedom in the area of component and system overdesign allowances, use of redundancy when necessary, and greater space or weight allowances where possible. From the user's standpoint, these same contractors must have impressed upon them the value of the use of "best quality" existing components, continued search for new and better equipment, the importance of keeping abreast of the current state-of-the-art, the absolute value of the use of simple components, and the elimination of unnecessary equipment or functions. With proper use of these techniques and procedures aided by consistent and complete failure reporting and equipment use feedback, there appears to be no reason why any of the three major Normal Environmental Control Subsystems cannot meet later Wing MTBF requirements of 20,000-30,000 hours.

VI. REFERENCES

1. "Reliability Report, 1 November 1961, Environmental Control Systems, WS 133A Technical Facilities," by American Air Filter Company, Inc., 200 Central Avenue, Louisville, Kentucky.

2. Reliability Section by C. Ryerson, et al., "WS 133A Technical Facilities Environmental Control System Study Final Report," by Holladay and Westcott, Engineers, 800 W. Colorado Boulevard, Los Angeles, California, 21 May 1962.

3. Reliability Analysis, D. R. Earles, Research and Advanced Development Division, Avco Corp., Wilmington, Massachusetts, RAD-TR-61-26, August 1961.

4. Minutes of Technical Direction Meeting No. 18, Environmental Control System for WS-133A, July 1961.